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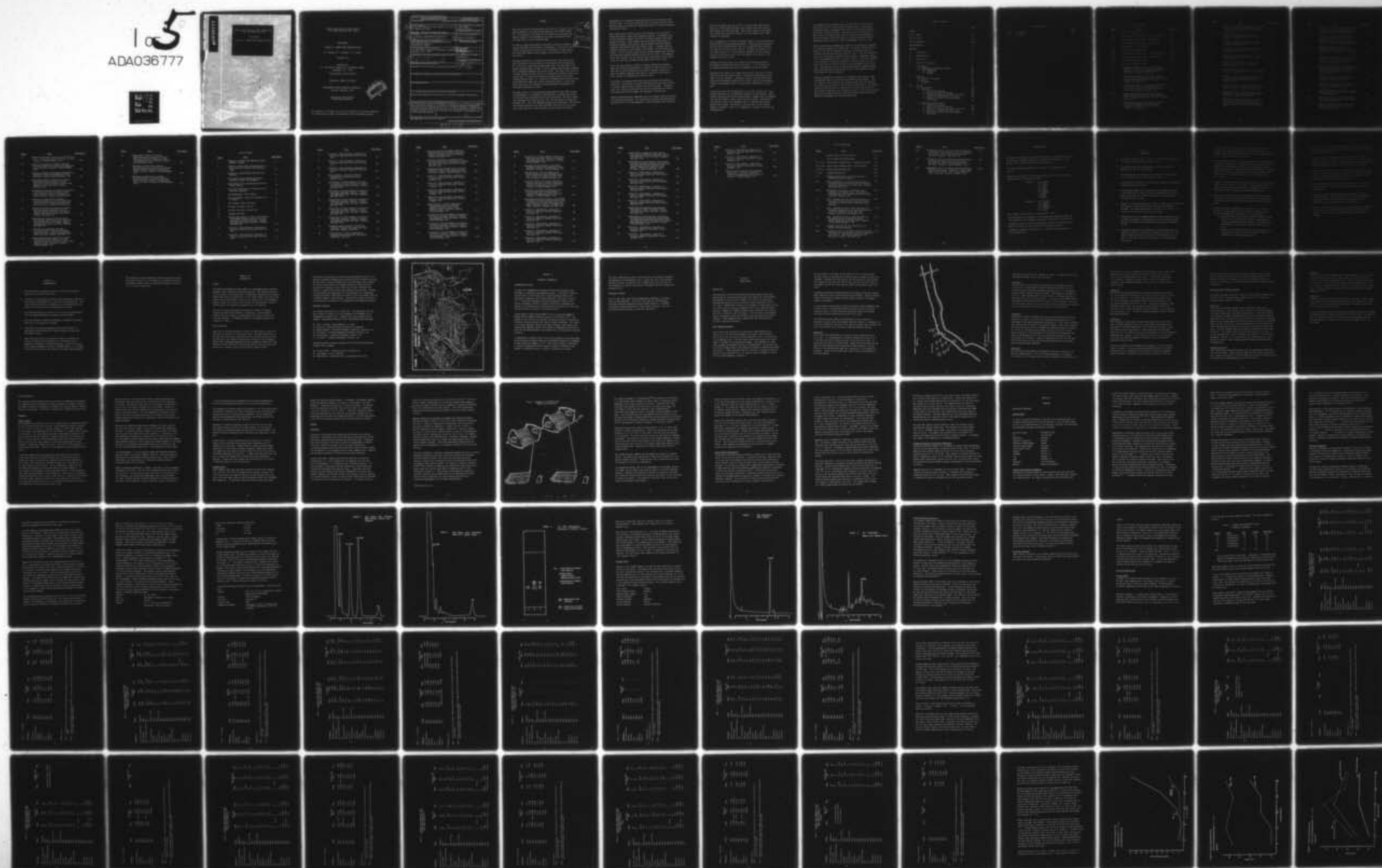

AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITION PLANTS

FINAL REPORT

VOLUME II - RADFORD ARMY AMMUNITION PLANT

# AQUATIC FIELD SURVEYS AT IOWA, RADFORD AND JOLIET ARMY AMMUNITION PLANTS

## FINAL REPORT

## VOLUME II - RADFORD ARMY AMMUNITION PLANT

R.L. Weitzel, R.C. Eisenman, & J.E. Schenk

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Two aquatic field surveys were carried out during 1975 at the Radford Army Ammunition Plant in Radford, Virginia. One survey was conducted during the spring period (15-20 May) and the other during the fall (30 October-4 November). Samples were collected from the New River in the vicinity of the nitroglycerin #2 area to allow for the evaluation of the species diversity and distribution of periphyton and benthic macroinvertebrates.

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## SUMMARY



This report describes the methodology and results of an aquatic field survey conducted at the Radford Army Ammunition Plant (RAAP) during 1975. The purpose of this study was to establish the biological and chemical impacts of the discharges from a major nitroglycerin manufacturing facility on its receving stream.

The RAAP is located approximately seven miles northwest of Radford, Virginia and eight miles southwest of Blacksburg. Activities at this facility include the production of TNT, nitroglycerin, single double, and triple base powders, rolled powders, nitrocellulose, oleum, and nitric acid.

The major watercourse at the RAAP is the New River, which borders the main plant area on the west and north, and separates the Nitroglycerin No. 2 Area (NG #2 Area) from the main plant area. The New River is the primary receiving water for most of the discharges from the RAAP, including those discharges emanating from the NG #2 Area. The flow of this river as it passes through the RAAP facility is controlled by release of water from Claytor Lake, a hydroelectric reservoir located several river miles upstream from the plant. On a typical day discharge rates of the New River at the RAAP will range from 15 cubic meters per second to 140-280 cubic meters per second, as a function of power generation requirements and anticipated precipitation events.

The major efforts of the investigations described in this volume focused on approximately 1.4 kilometers of the New River, including that stretch of the river where effluents from the NG #2 Area enter. Two field surveys were conducted, one in May and June, 1975, and the second in October and November, 1975. Six river sampling stations were established. Two stations were located upstream of any known discharge from the NG #2 Area, three were located near NG #2 Area effluents, and one station was located

approximately 0.9 kilometers downstream from any known discharges from the NG #2 Area. In this way background river conditions could be differentiated from any localized and "downstream" effects of outfalls emanating from the NG #2 Area.

Water samples were collected at the river stations on five occasions during each survey, using a grab sampling technique. In addition, each of four industrial outfalls from the NG #2 Area was sampled five times during each survey. These samples were characterized with respect to nutrients, minerals, heavy metals, and two specific munitions-related compounds, nitroglycerin and nitro-diphenyl amine. A similar analysis scheme was applied to river sediment core samples collected during both surveys. In all, 95 water samples and 32 sediment samples were collected and extensively analyzed during the course of this study. The chemistry effort also included a 48 hour dirunal study during which pH and conductivity was monitored upstream and downstream from the NG #2 Area.

River biota was studied in terms of periphyton diatom and non-diatom algae and benthic macroinvertebrates. The goal of this portion of the study was to relate differences in biological community structure to water and sediment chemistry data and/or to location in and along the river relative to discharges from the NG #2 Area.

Collections of periphyton were taken from both natural and artificial substrates. The material collected from natural substrates was utilized for species identification of diatom and non-diatom algae. Periphyton taken from artificial substrates was used for determination of species occurrence, ash-free dry weight, and chlorophyll concentration.

Benthic macroinvertebrate communities were also sampled using both natural and artificial substrates. The collections of benthic macroinvertebrates were used only for the determination of species abundance and occurrence.

Although in general the water quality of the New River remains quite good as it flows through the study area, chemical data does indicate some impacts from RAAP discharges. Three trends appear in the aqueous river survey data, involving increases in total organic carbon (TOC), nitrogen, and chromium.

The concentrations of TOC were appreciably higher at the most downstream station than at the most upstream station. During the May-June survey, mean TOC levels increased from 4 mg/l at the upstream control station to 22 mg/l at the most upstream station. However, an analysis of the TOC loads carried by NG #2 Area outfalls indicated that the observed increase in TOC levels in the river was probably not a result of discharges from the NG #2 Area.

Chromium levels were found to be higher at the downstream stations. The highest concentration found was 0.048 mg/l. It is unlikely that the observed increases were due to discharges from the NG #2 Area.

Nitrogen levels tended to be higher below outfalls from the NG #2 Area than at the upstream control station, although the differences were not large (0.34 mg/l maximum). Increases in nitrate nitrogen levels were particularly noticeable during the Fall survey, when the river sampling schedule corresponded closely to the production schedule at the NG #2 Area.

Nitroglycerin was found intermittently in the water column at all river stations, generally at concentrations between 0.01 and 0.02 mg/l. Nitroglycerin was also found at the control station, possibly due to discharges from the Roll Powder #1 Area, located further upstream. Nitroglycerin was detected in only three sediment cores, at conentrations slightly greater than 1 mg/kg. The absence of nitroglycerin in most sediment samples is probably a result of a combination of chemical hydrolysis and biodegradation.

The presence of nitro-diphenyl amine and high levels of lead in sediments below outfall #22, and elevated concentrations of some metals and organic matter in sediments below outfall #18 indicated localized effects due to these effluents. Detectable levels of nitroglycerin were found in the aqueous phase and low levels of both nitroglycerin and nitro-diphenyl amine were found in the sediment phase at the most downstream station, located 0.9 miles downstream of the NG #2 Area.

Minor variations were observed with respect to the biological community, but these were generally not significant. Variations in species diversities of the various communities could not be correlated with the effluents from the nitroglycerin production areas. The most noticeable effect on the biological community was in regards to periphyton production in the immediate vicinity of certain outfalls. Production appeared to be inhibited in the area of outfalls 18 and 19, however this inhibition could not be directly related to waste discharge from the NG #2 Area. The stimulatory effect on periphyton production observed immediately downstream from outfall 20 may be due to the increased nitrogen levels observed directly upstream.

Generally speaking little definitive information with respect to the environmental impacts of nitroglycerin production was obtained. This is a result of the relatively low discharge volume from this facility with respect to the volume of flow in the receiving waters. Any further studies at this site with the same objective should take the form of more intensive sampling in the immediate vicinity of the various outfalls which might provide indication of localized affects prior to the disipation of contaminants into the main water body.

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## SECTION I
## CONCLUSIONS

1. The primary chemical impact of the N.G. #2 area on the New River is an increase in aqueous phase nitrogen levels.

2. Nitroglycerin was found intermittently at all river stations, generally between 0.01 and 0.02 mg/l.

3. Nitroglycerin was also observed at the control station, possibly due to discharges from the Roll Powder #1 area.

4. Nitroglycerin was detected in three sediment cores at a concentration slightly greater than 1 mg/kg.

5. Aqueous phase chemical data indicates that the dominant influence in the study area as a whole is due to discharges from the south side of the river (i.e. opposite from the N.G. #2 area) rather than from the N.G. #2 area.

6. Presence of NDPA and high levels of lead in sediments below outfall #22, and elevated concentrations of lead, mercury, COD, Kjeldahl nitrogen , and hexane extractables in sediments below outfall #18, indicated localized effects due to these outfalls.

7. Nitroglycerin and nitro-diphenyl amine are being transported out of the area as evidenced by the detection of NG in the aqueous phase and both NG and NDPA in the sediment phase at the most downstream station.

8. Significant variations were observed in periphyton diatom species diversity collected on artificial substrates during May-June, 1975. These variations occurred in the area of outfall numbers 18, 19 and 20. This trend was not repeated during the October-November 1975 survey.

9. Diatom species diversity collected on natural substrates was two to three times higher than observed on artificial substrates. Observed variations in diatom species diversity on natural substrates were not significant during either survey.

10. Pennate diatoms comprised the largest percentage of periphyton algae on artificial substrates. No significant shifts occurred in species dominance or association of common species of periphyton diatom and non-diatom algae. Variations in species associations of periphyton algae involved the loss and recurrence of rare and uncommon taxa which could not be related directly to waste discharge from the N.G. #2 area.

11. Trends of periphyton ash-free dry weight ($mg/m^2/day$) and chlorophyll a ($mg/m^2/day$) were similar to each other. This was common during both surveys although periphyton production as estimated by these two measurements was lower during the October-November survey.

12. Significant variations were seen in periphyton ash-free dry weight during the May-June and October-November surveys, while variations in chlorophyll a were significant only during the October-November survey.

13. Periphyton production appeared to be inhibited, i.e., reduced, in the area of outfall numbers 18 and 19 while a stimulatory affect was observed immediately downstream from outfall number 20.
    a. Inhibition could not be directly related to waste discharge from the N.G. #2 area and was probably a combination of natural periphyton variation typical to fast flowing lotic environments as well as waste discharge from the N.G. #2 area.
    b. Stimulation of periphyton production may be associated with the increase in nitrogen levels from outfalls directly upstream from a single sampling station.

14. Apparent affects of waste discharge from the N.G. #2 area on periphyton were localized and recovery appeared to occur with distance downstream from the discharge points.

15. Species diversity of benthic macroinvertebrates on artificial substrates varied in the area of outfall numbers 18, 19 and 20 during the spring and fall surveys. These variations were not significant and could not be directly related to wastes from the N.G. #2 area.

16. Little variation was seen in species diversity of benthic macroinvertebrates collected from natural substrates. There were no significant shifts in species dominance at any station except immediately below outfall number 20 during the May-June survey.

17. Benthic macroinvertebrate species characteristic of the faculatative-intolerant type were found as being common at all stations of the study area.

18. Observed population changes in species associations of benthic macroinvertebrates collected from artificial and natural substrates during both surveys could be associated with shifts in water chemistry although variations were not significant.

19. Benthic population variations were localized and reflect a combination of natural population variation and response to wastes from the N.G. #2 area as well as munitions operations opposite the N.G. #2 area.

## SECTION II
## RECOMMENDATIONS

1. A second survey be conducted at RAAP, to focus on the localized affects due to outfalls #18 and #22.

2. A study of the attenuation of nitroglycerin wastewaters in the NG #2 area should be performed prior to any other field survey work. This could include dye studies to determine path of discharges from the outfall to the river, as well as mixing with the river.

3. The downstream extent of pollution from NG #2 area be determined by water and sediment sampling and analysis for NG and NDPA.

4. Field and laboratory studies be performed to determine the environmental fate of nitroglycerin and NDPA.

5. Additional field studies regarding nitroglycerin pollution at RAAP should include definition of other NG sources, such as the Roll Powder #1 area.

6. Additional field survey and laboratory studies to determine the extent of inhibition and stimulation of the periphyton microcommunity in response to nitroglycerin wastes. This would involve more localized sampling at specific discharge points, i.e., outfalls 18 and 22, and the use of these wastes in an algal assay experiment.

7. More extensive localized sampling of benthic macroinvertebrates at outfalls 18 and 22 if the results of the laboratory bioassay experiments indicate affects on macroinvertebrates at levels of 1.0 - 2.0 mg/l nitroglycerin.

## SECTION III
## INTRODUCTION

### GENERAL

The Radford Army Ammunition Plant (RAAP) is a government-owned, contractor operated, class II military industrial operation. The principal activity at this facility is the manufacture of propellants, explosives and chemicals. Capabilities include the production of TNT, single, double, and triple base powders, and rolled powders; as well as the production of the intermediate products oleum, nitric acid, nitrocellulose, and nitroglycerin. Hercules, Incorporated is the contractor responsible for this operation.

The RAAP is located approximately seven miles northwest of Radford, Virginia and eight miles southwest of Blacksburg. The main Radford manufacturing area consists of approximately 4154 acres, of which 2800 acres are developed. A schematic diagram of the manufacturing area is presented in Figure 1.

### RECEIVING WATERS

There are two receiving streams of interest on RAAP property, only one of which was of concern in this particular study. The major watercourse at the RAAP is the New River, which borders the main plant area on the north and west and is the primary receiving water for most of the discharges, notably those discharges emanating from the nitroglycerin production area. Strouble's Creek drains most of the southern half of the main plant area, and was not a concern of the particular effort reported herein.

The New River originates near the North Carolina-Virginia border, flows generally northward through western Virginia and West Virginia, and joins the Elk River to form the Kanawha River near Charleston, West Virginia. The flow of the New River as it passes through the RAAP facility is controlled by releases of water from Claytor Lake, a hydroelectric reservoir located several river miles upstream from the plant. Release of water during power generation, or in anticipation of a significant precipitation event, raises the water level of the river several feet for a variable length of time each day. This presents a major difficulty in the satisfactory performance of a comprehensive field sampling program.

## PERSONNEL CONTACTED

The contract was initiated on 1 March 1975. An orientation visit was made at RAAP on 24 March 1975 by two members of the ENCOTEC staff, accompanied by Captain John P. Glennon, the project monitor for the USAMRDC. Individuals contacted at that time included the following:

Mr. John C. Horvath - Chief Engineer, U.S. Army
Dr. Bolleter - Technical Director, Hercules, Incorporated
Mr. Donald Mayberry - Pollution Abatement Coordinator, Hercules, Inc.
Mr. Fred Willis - Pollution Abatement Department, Hercules, Inc.
Mr. Leonard Smith - Technical Department, Hercules, Inc.
Mr. Ed Ziegler - Technical Department, Hercules, Inc.

Additional Radford personnel contacted at the first field visitation, 29 April 1975, included:

Mr. Forrest Farley - Pollution Control, Hercules, Inc.
Mr. John Hannan - Chief of Security
Mr. James Marsico - Production Chief, nitroglycerine two area

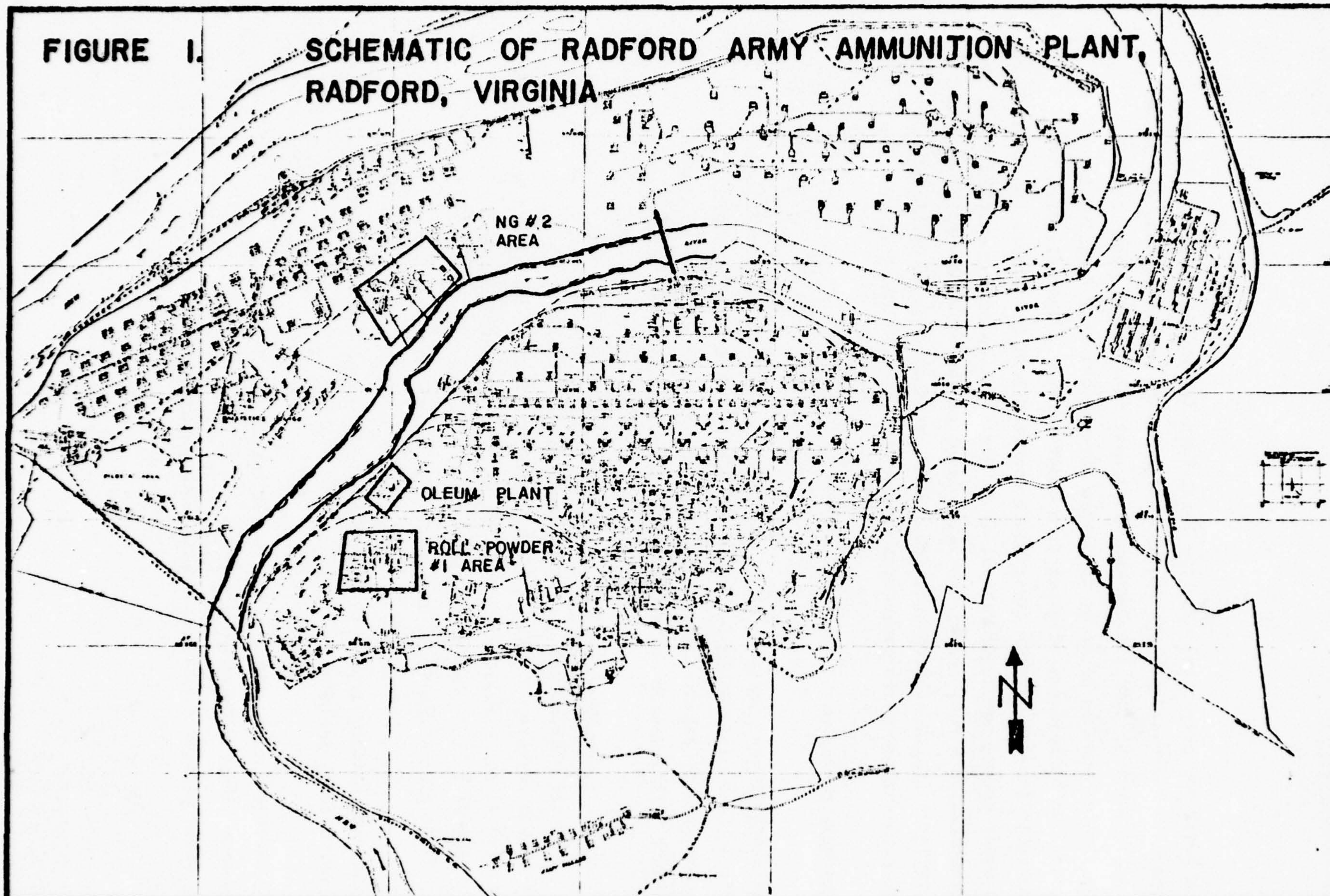



FIGURE I. SCHEMATIC OF RADFORD ARMY AMMUNITION PLANT, RADFORD, VIRGINIA

## SECTION IV

## HISTORICAL INFORMATION

### COMPREHENSIVE SURVEYS

At least four comprehensive ecological surveys have previously been performed at the Radford Army Ammunition Plant. A biological survey of the New River, and the affects due to RAAP discharges thereon, was performed by personnel from Virginia Polytechnic Institute in June of 1971[1]. This study determined a localized deleterious effect due to certain discharges, however no specific effects were determined with respect to the effluent from the nitroglycerin production area, which was the specific area of concern of the present study.

A water quality survey was performed by the U.S. Army Environmental Hygiene Agency (USAEHA) during the period of 4-18 October 1971[2]. The purpose of this study was to evaluate the aquatic biological condition of Stroubles Creek and the New River below the waste discharges. The results of the study indicated several areas where biological water quality was significantly degraded, however the location of sampling stations did not allow for the identification of any effects due to nitroglycerin production effluents.

A comprehensive ecological survey of the entire Radford area was performed by the Ecological Research Office of the Biomedical Laboratory at Edgewood Aresenal during the summer of 1973[3]. This report presents a compilation of potential damaging effluents, however no specific information with regards to ecological effects of specific discharges is provided.

The fourth comprehensive survey of this facility was performed by WAPORA, Incorporated on 16-20 September 1974[4]. As was the case in the previously mentioned studies, the protocol of the WAPORA survey did not allow for the delineation of effects due solely to discharges from the nitroglycerin production area.

## MONITORING PROGRAM

Prior to July 1974, water quality sampling was performed on a monthly basis by RAAP personnel. On 28 July 1974, RAAP was issued National Pollutant Discharge Elimination System (NPDES) Permit No. VA 0000248. This permit requires monitoring of twenty eight discharges, with most monitoring being performed on a once per week basis.

SECTION V

FIELD SURVEY

## INTRODUCTION

The work effort of the field monitoring and water quality survey was concentrated at the nitroglycerin number two (NG#2) area of the Radford Army Ammunition Plant and that segment of the New River immediately upstream and downstream from the industrial waste discharges from the NG #2 area. Samples were collected for assessment of water quality in the river proper and for chemical characterization of the industrial waste outfalls. Samples for sediment chemistry were collected in the river in the area of individual waste discharges. The river biota was studied in terms of periphyton diatom and non-diatom algae and benthic macroinvertebrates. These communities were sampled both from artificial and naturally occurring substrates.

### River Sampling Stations

Due to the routine operations of hydroelectric power generation at Claytor Lake, and the close proximity of the RAAP to this reservior, water depth, flow, and velocity varied extensively over a 24 hour period at the sampling sites. Flow was lowest during early morning and usually began to increase in late morning and midday. Flow remained at a high level through the afternoon and into the evening hours. On a typical day flow would increase from 15 cubic meters per second to 140-280 cubic meters per second . These conditions made the collection of samples during the period of low to moderate flow, i.e. morning hours, preferable to afternoon or evening sampling. (Appendix I).

In the vicinity of the RAAP, the New River is 120 to 150 meters wide. The main channel is approximately 40 meters wide and ranges in depth from one meter to greater than three meters over the stretch of river studied. This channel follows the north bank of the river past the NG #2 Area, so discharges from the NG #2 Area may mix rapidly with the main flow of the river.

In general, artificial substrate samplers were anchored in the main channel. Water samples were also collected from the main channel. Natural substrate benthos collections were made in shallow water as close to the basket samplers as possible.

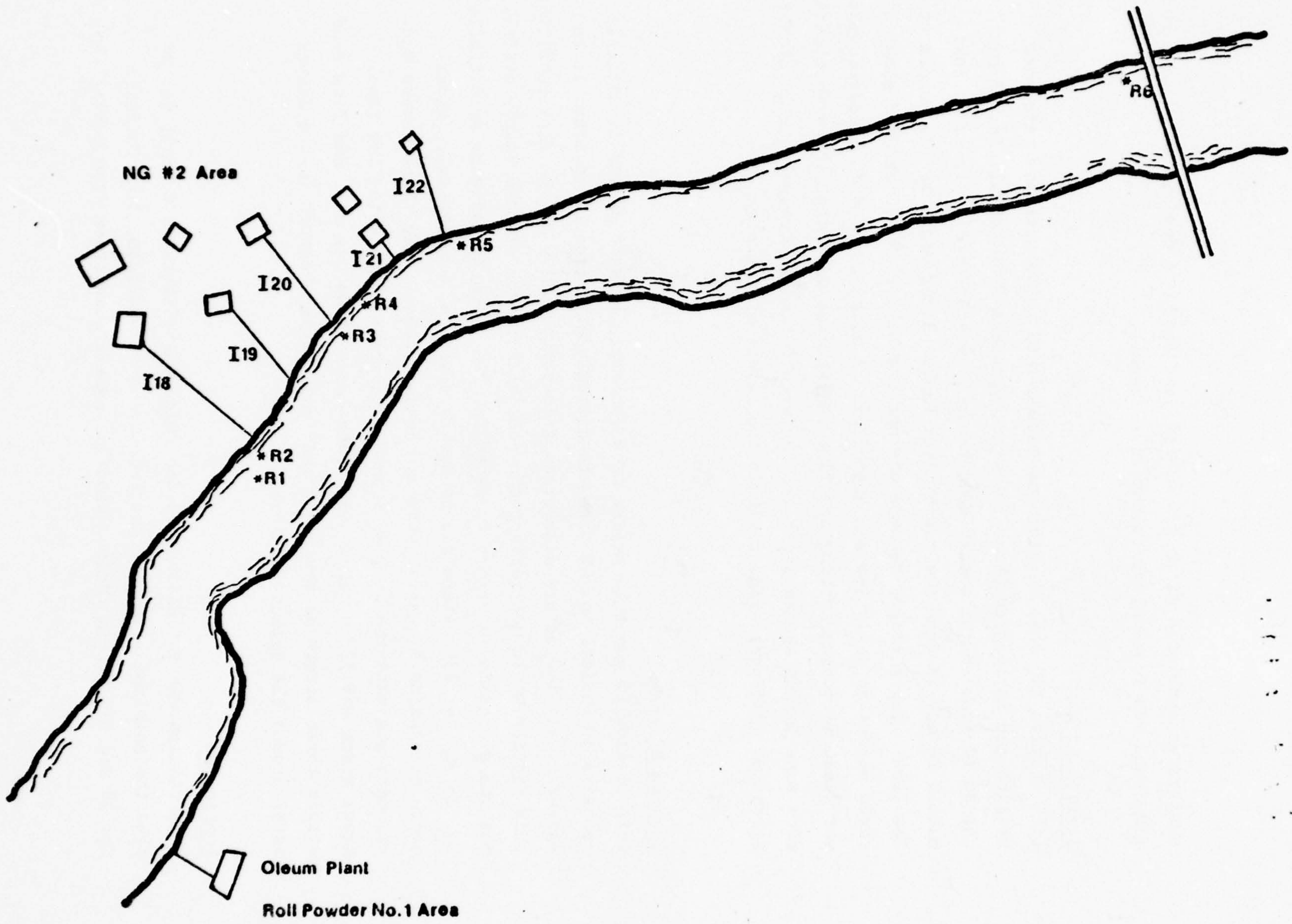
At some stations this resulted in natural substrate benthos sampling being collected five to fifteen meters toward mid-river from the artificial substrate anchors. Natural substrate periphyton samples and sediment cores were collected along the north bank of the river.

The following station scheme was established for the collection of biological, aqueous phase, and sediment chemistry (Figure 2). Distances are given with reference to the north river bank and nearest waste discharge and are at the location of the artificial substrate anchoring devices.

Station R1 -

This station was established as a reference station upstream from the NG #2 area. It is approximately 82 meters upstream from outfall No. 18 of the NG#2 area and is within 28 meters of the north river bank. At this point the river is 125 meters wide. Depth varied from less than one meter (0.75 m) during low flow conditions of early morning to one and one-half to two meters during high flow conditions of late morning and afternoon. During low flow conditions current velocity was measured at 0.20 meter/second.

FIGURE 2 Schematic of Radford Army Ammunition Plant, Virginia. Study Area



Substrates consisted of rock, pebbles, and sand. A deposition of silt and fine sand was found close to the river bank.

Station R2 -

Like Station R1, this station was established as an upstream reference station and is located about 50 meters upstream from Outfall No. 18 of the NG #2 area and 32 meters downstream from station R1. It is approximately 20 meters from the north river bank. River width is 125 meters at low flow. Depth ranged between one and one-half (1.5) meters and about three meters at daily low and high flow. A velocity of 0.73 meters/second was measured during morning low flow. Substrates were similar to station R1 with some larger stones and rocks, between 30 and 60 centimeters in diameter. Silts and sand were evident within two meters of the river bank.

Station R3 -

This station is about 20 meters from the north river bank and is directly opposite of Outfall No. 20 from the nitroglycerin production area. It is approximately 180 meters downstream from station R2. Due to flow conditions this station would not reflect the possible effects of this nearby outfall, but was placed in an effort to determine the potential affects of Outfalls No. 18 and 19, 130 meters and 55 meters upstream, respectively. River depth at station R3 varied between one and one-half and three meters and velocity was measured at less than 0.6 meters/second during low flow. River width was 120 meters. Substrate composition was silt and fine sand within three meters of the river bank and scoured bedrock in the deeper water around the basket samplers.

Station R4 -

This station was established to determine the effects of Outfall No. 20 plus the combined effect of the two effluents upstream, i.e. Outfalls No. 18 and 19. It is located about 55 meters downstream from Outfall No. 20

and Station R3, and is 14 meters from the north river bank. Depth varied between one and one-half and two and one-half meters with a current velocity of 0.15 meters/second at low flow. At this point river width was 120 meters. Substrates included rocks, stones, and pebbles, and consisted of more extensive deposits of fine sand and silt than found at other stations.

Station R5 -

Station R5 was located approximately 180 meters downstream from station R4. River width was 115 meters with a depth of two and one-half to three and one-half meters. It was established downstream from waste Outfall No. 22 and would show the potential effects of the combination of the five waste discharges from the NG #2 area. Substrates consisted of large and small rocks, stones, and occasional silt deposits near the bank. Velocity at low flow was recorded at 0.15 meters/second. Due to fluctuating conditions of flow, artificial substrate samplers from this station were never recovered.

Station R6 -

This station was established 915 meters downstream from station R5 and about 25 meters upstream (west) of the river bridge connecting the two main areas of the RAAP installation. River width was 148 meters at low flow and the station was located 15 meters from the north river bank. Depth was one to two meters and velocity was measured at 0.18 meters/second. Substrates were composed of rocks, stones, and sand in the area around the artificial substrate samplers, with areas of silt, and detrital deposition along the bank.

In total the sampling area encompassed approximately 1,362 river meters (about 0.8 mile). As stated previously measurements given for station descriptions are in reference to the position of artificial substrate anchoring devices. Stations are not pin-point locations but refer to

zones or areas around the artificial substrate samplers. Due to water depth it was most often difficult to collect substrate samples in the immediate vicinity of the sampling devices but attempts were made to restrict the station zones to areas nearest the industrial waste discharge in question.

Industrial Waste Sampling Stations

Five waste discharge sources were sampled for water quality analysis from the NG #2 area. These were Outfall Numbers 18, 19, 20, 21 and 22 as numbered by plant operations personnel.

Outfall 18 -

Water from this outfall includes wastes from several areas of the nitrating process. This includes surface runoff, cooling water, washout from spent acid storage, and washout from nitraters. Wash water from the acid storage and nitrater are neutralized with soda ash before discharge. These waste waters flow through a catch basin with an under flow weir which separates the floating material and the precipitate, allowing the clarified wastes to flow to the river. The discharge opens to the bluff above the river and then flows in an open ditch toward the river some 15-30 meters below. The waste stream enters an underground cavern about half way down the bluff. A dye study located one exit point along the river bank. It is this discharge point that is referred to as Outfall No. 18 in previous paragraphs. However, it is possible that flow from Outfall No. 18 also enters the river at other points upstream or downstream from the known discharge point.

Outfalls 19 and 20 -

These wastes arise from process waters used in transporting nitroglycerin and wash down water. Wastes include acetone and about three percent soda ash. Similar to Outfall No. 18 these wastes flow through a catch basin and clarifier prior to flowing down the bluff to the river.

Outfall 21 -

Outfall 21 recieves the washdown water from the premix area. In addition to nitroglycerin, wastes include small amounts of nitrocellulose and acetone. This outfall flows briefly every afternoon when the premix area is cleaned up. After leaving the premix area these wastes likewise flow in an open ditch toward the river. Frequently, the total flow is so small that it either evaporates or soaks into the ground before any wastewater reaches the river.

Outfall 22 -

Outfall 22 carries the wastes from the slurry mix process. Wastes include small amounts of o-nitro-diphenyl amine (NDPA), lead compounds, and nitroglycerin. Like the previous waste discharges this outfall flows in an open ditch down to the river below.

All five outfalls flow in open ditches which expose the wastes to limestone rock and clay soils as they flow down the bluff to the river. The vertical drop of the bluff is between 15 and 30 meters requiring about one hour for the waste water to reach the river from its discharge point in the NG #2 area.

## FIELD METHODOLOGY

The sampling program presented within this section is summarized in Appendix O. This summary indicates the number of samples attempted, the number collected, the number analyzed and subsampled, the number lost, and the number of samples stored or not analyzed. The scheme is presented on a parameter/station basis.

### Chemistry

#### Aqueous phase -

Water samples were collected at five river stations and four industrial outfalls on five occasions during the May survey. River sampling was done at station R-1, R-3, R-4, R-5, and R-6. Since both station R-1 and R-2 were expected to be upstream of any discharge from NG Area Number 2, no samples were collected at station R-2. The river sampling was done in the morning during river low flow conditions with the exception of samples collected in the afternoon of May 20. The rational for morning sampling was that since effluent dilution would be less at this time, changes in river water quality would be more noticable. Industrial outfalls I-18, I-19, I-20, and I-22 were sampled five times during this survey. Outfall I-21 was sampled only once during the first survey.

A different approach to river sampling was used during the fall survey. Rather than collecting all samples during river low flow conditions, an attempt was made to coordinate river sampling with production schedules in the NG area. This required two sampling trips per day. Stations R-1 and R-5 were sampled in the afternoon. The R-1 sample was a control and the R-5 sample was designed to pick up the effects of outfall number 22. In the evening, R-1 was sampled a second time along with R-4. The R-4 samples were taken just downstream of outfall number 20. Station R-6 was alternately sampled during the day with R-5 and at night with R-4. Because of the problems involved in night sampling as well as its close proximity to station R-4, no samples were taken at station R-3. All industrial outfalls from NG Area #2 were sampled five times during the second survey.

Sample collection - During the first survey, three grab samples were collected at each river station with a Van Dorn Bottle and composited in a bucket. One grab was taken next to the biological station marker, and one five to ten yards on either side of the marker. During the second survey, the river was sampled with a single grab at each station using a five gallon bucket. The river samples were collected closer to shore in the fall at stations R-4 and R-5 in an effort to insure that outfall plumes from I-20 and I-22, respectively, would be included in the sampling program.

Generally the industrial samples were obtained by filling a bucket at the end of the outfall trough at the top of the bluff overlooking the the river. An effort was made to sample the outfalls when it was known that the line being sampled was in full operation. In addition to the grab samplings, two eight hour composites were collected from each of the four primary outfalls during the first survey using automatic samplers. These samplers were set to draw a sample every twenty minutes over an eight hour period. One composite represented eight hours of production time and the other represented eight hours of non-production at each outfall.

Field measurements - In situ dissolved oxygen and temperature measurements were made at the time of sample collection. Dissolved oxygen was measured with a polarographic type gas sensing probe. Depth and flow measurements were made periodically during the sampling program as described earlier in this section.

Sample storage and preservation - Samples were split into five separate containers in the field. Two one liter polyethylene bottles were filled and put on ice. One of these was used on the day it was collected for pH, alkalinity, and conductivity measurements and for setting BOD's. The other container was kept under refrigeration and transported back to Ann Arbor for determination of solids, chloride, sulfate, and hardness.

A third polyethylene bottle designated for heavy metal determinations was filled and preserved with nitric acid (1% final concentration).

The subsample for nutrient analysis was placed in a 2.4 liter glass bottle, preserved with sulfuric acid (final concentration 0.2%), and kept under refrigeration until all analyses were completed. For the industrial samples with exceptionally high alkalinities, sufficient sulfuric acid was added to lower the pH to less than 2.0.

Subsamples for munition compounds analysis were placed in four liter brown glass bottles and kept on ice until evening. At that time 50 milliliters of benzene was added and mixed with the water samples. The samples were kept refrigerated until extraction was completed at a later date.

Diurnal study - A 48 hour diurnal study was carried out to discover whether or not there were any noticable daily variations in pH or conductivity in the river. Because station location precluded manual sampling on a 24 hour basis, automatic sequential samplers were used. One sampler was set slightly upstream of station R-1 and the second was positioned downstream of station R-6. A sample was drawn every hour, and every 12 hours the samples were collected and pH and conductivity measured. Samples were kept chilled with ice during the 12 hour shift to minimize changes in pH and conductivity.

Sediment Phase -
Three sediment cores were collected at each of the five river stations (R-1, R-3, R-4, R-5, and R-6) during the first survey. Because the river bottom itself is primarily bedrock or stone and gravel with some sand, cores were taken along the bank in backwaters where finer sediments had accumulated. In some cases cores were taken from the bank itself

between the high and low water marks. In November, the sediment sampling scheme was modified somewhat in an effort to obtain some "worst case" sediments. Cores were collected at R-1 and R-6 as before. In addition, three cores each were collected along the river bank in the immediate vicinity of outfalls 18, 19, 20, and 22. Cores were obtained by pushing a two inch polycarbonate core tube into the sediment, capping the top, withdrawing the core tube, and capping the bottom. The cores were placed on dry ice in the field, and kept frozen until processed for analysis.

## Biology

### Periphyton -

Collections of periphyton were taken from both natural and artificial substrates. The material collected from natural substrates was utilized for species identifications of diatom and non-diatom algae. Periphyton taken from artificial substrates was used for determination of species occurrence, ash-free dry weight, and chlorophyll concentration. Collecting periphyton from both natural and artificial substrates enabled the determination of the complete attached algal community and to identify the population available to colonize the artificial substrates.

Natural substrates - Sampling from natural substrates included the haptobenthos, i.e., solid surfaces such as submerged rocks and wood, and the herpobenthos, i.e., growths on mud or mud/sand surfaces[5]. The solid surfaces of rocks and wood were scraped with a pocket knife and forceps and the material was placed in vials. Collections from rock surfaces and wood surfaces were treated independently from each other. Several submerged rock and wood surfaces were sampled as well as sampling all possible positions, sides, or areas of these substrates with reference to direction of flow and direction of sunlight. An attempt was made to

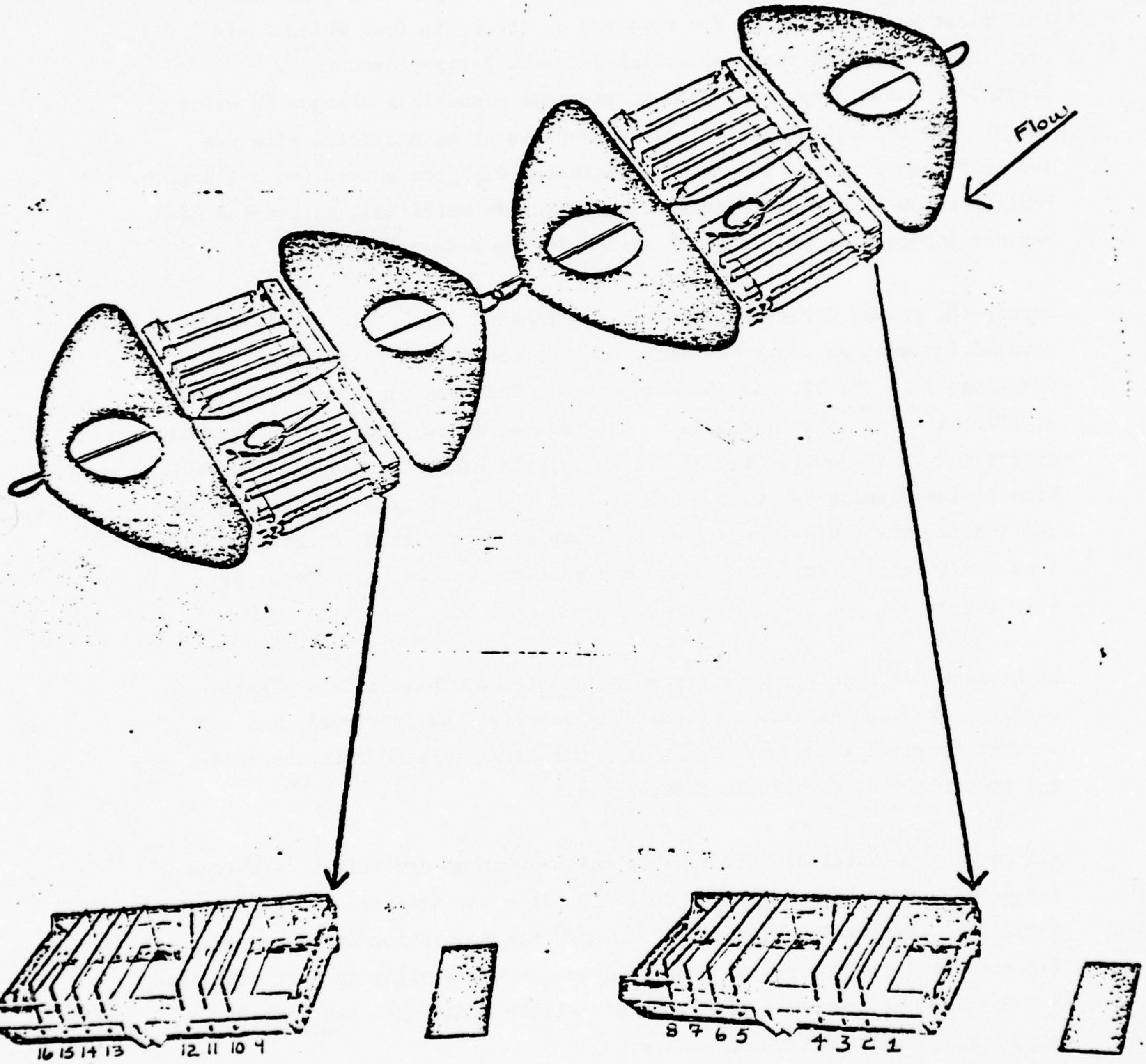
sample all possible microhabitats on rock and wood surfaces. This was to insure a sample representative of the entire attached algal community and was an attempt to prevent the sole sampling of isolated microhabitats which may be dominated by a select species. Vials were appropriately labeled and the collections were preserved with a two percent formalin solution.

Material growing on the surface of sediments was collected by gently lifting the surface "film" or "floc" with a knife blade and by pipetting the "floc". Similar to sampling the haptobenthos, many surfaces were collected to prevent the sampling of a single isolated species or species-complex which could inhabit a unique zone. Again the attempt was made to collect from all possible zones or areas of the herpobenthos. The pipets used for removing the "films" or "flocs" had a wide diameter opening to prevent size discrimination of periphytic organisms. Sediment surface samples were placed in a single vial and preserved with a two percent formalin solution. Vials were appropriately labelled and the sample treated independently of the samples collected from rock and wood surfaces.

Artificial substrates - Artificial substrates samplers were used to achieve consistency between collections at the different stations and between different sampling periods. The artificial substrates guaranteed comparable surfaces for colonization as well as regulating the period of colonization and periphyton growth. Two substrate samplers, Periphytometers™* were attached in tandem and each loaded with eight glass microscope slides, one inch by three inches in dimension (2.54 by 7.62 centimeters) (Figure 3). Slide positions were numbered to maintain a consistent sampling routine where slides from predetermined positions would be used as replicates for either species identifications, chlorophyll measurements, or dry weight determinations.

*Design Alliance, Inc.

Figure 3. Schematic of Periphytometer
Showing Slide Position



The tandem arrangement of Periphytometers™ was anchored at the stations by a light-weight cable attached to a steel stake or cinderblock anchor, depending on water depth and flow conditions. A spherical styrofoam lead-float was attached to the free end of the cable from which a six foot length of nylon rope was attached to the Periphytometers™. Sufficient cable length was used to accomodate possible changes in water depth. The incubation period of the samplers at each station site was not less than 30 days to permit sufficient periphyton growth for collection. Periods of 30-45 days were necessary to achieve sufficient periphyton mass, yet not approaching the stage of sloughing, as determined visually.

During the spring survey slides from positions 2, 5, 8, 11, and 14 were removed for species identification. During the fall survey slides from positions 3, 6, 9, 12, and 15 were taken. This procedure was applied at all stations. The five slides were treated as replicates and compared accordingly. The collection of slides in this manner prevented a possible bias in the results due to the position in the artificial samplers as the replicates were taken from all of the sampler rather than adjacent slides from an isolated area. Hopefully this routine reduced any effects of sampling error.

Each slide was gently removed from the sampler and placed in a plastic bottle. The samples were appropriately labelled and preserved in a two percent formalin solution. Periphyton was later scraped from the slides and prepared for microscopic observation.

All periphyton material used for the measurement of dry weight, ash-free dry weight, and chlorophyll was collected from the artificial substrate samplers. Samplers were prepared and anchored as previously discussed. The routine for slide position and collection was similar to that described for species occurrence. Five replicate slides were taken for both dry weight and chlorophyll measurements.

During the spring survey (May-June) slides were taken from positions, 1, 4, 7, 10, and 13 and prepared for dry weight determinations. During the fall survey (October) slides were taken from positions 2, 5, 8, 11, and 14 (Figure 3). The slides were gently removed from the sampler and placed in separate plastic bottles. Samples were labelled and preserved in a two percent formalin solution. Periphyton was later scraped from the slides and prepared for dry weight determinations.

Samples for chlorophyll analysis were collected from slide positions 3, 6, 9, 12, and 15 during the spring survey. This order was changed to positions 1, 4, 7, 10, and 13 during the fall survey (Figure 3). Slides were gently removed from the samplers and placed in separate plastic bottles with distilled water. Samples were labelled and immediately put on ice to reduce biological activity and chlorophyll breakdown. Within two hours after collection, the periphyton was scraped from the slides and filtered onto 4.25 centimeter, 0.45 micron Whatman GF/C glass fiber filters. The filters were folded and placed in labelled plastic petri dishes. These samples were immediately frozen and held for pigment extraction and analysis in the laboratory.

Benthic Macroinvertebrates -
Collections of the benthic macroinvertebrate community were taken from both natural and artificial substrates. Fluctuating hydrologic conditions found in the New River at the Radford Army Ammunition Plant were sufficient to create substrate variation and alteration with time and distance between stations. In an effort to achieve valid comparisons between samples collected at these stations, artificial substrate samplers were employed to eliminate or reduce the variable of substrate types[6]. Collections were likewise taken from the natural substrates to determine background populations and to indicate the maximum potential population available to colonize the artificial substrate samplers. The collections of benthic macroinvertebrates were used only for the determination of species abundance and occurrence.

Natural substrates - Five replicate samples from naturally occurring substrates were collected by the kick method at each station . Approximately a four square foot (0.37 square meter) area was disturbed by kicking and digging in the sediment with one's boot toe immediately upstream from a two foot by three foot (0.61 by 0.91 meter) fine mesh screen. This disturbance and agitation dislodged the benthic organisms from the rocks, rubble, and silt/sand sediments causing them to drift and be caught on the screen. Disturbance of these substrates extended to a depth of about four inches (10 centimeters). The screen was then carefully lifted from the water and the organisms were washed into a No. 30 U.S. Standard sieve. This material was washed and placed in an appropriately labelled plastic bottle. Specimens clinging to the screen and sieve were removed with forceps and placed in the sample bottle. All samples were preserved with a two-tenths (0.2) percent rose bengal solution in 80 percent isopropyl alcohol[7].

Sampling by the kick method is restricted to depths of less than four feet (1.2 meters), however the depth at the stations where artificial substrates were anchored was most often greater than four to five feet (1.2 to 1.5 meters). Consequently samples taken from natural substrates were not always adjacent to the artificial substrates due to water depth, however they were taken as close to these artificial substrates as possible.

Artificial substrates - The use of rock basket samplers was employed to maintain consistency in collections between replicates and between sampling stations. Typical Bar-B-Q baskets were filled with 30 rocks of two to three inch (5 to 8 centimeters) diameter and held closed with the anchoring cable[6,8]. Due to the changing characteristics of flow and velocity in the New River the basket samplers were anchored and layed on the river bottom rather than suspended from floats in the water column. Five replicate basket samplers were attached to cinderblock anchors by six foot lengths of light-weight steel cable. The samplers were arranged in a radial design around the anchors at each station.

Following an exposure period of not less than 40 days, the basket samplers were collected individually on a random basis. Baskets were placed in a No. 30 mesh screen bottom wash bucket, the cables were cut, and the baskets were brought to the water surface. The samplers were then placed in five-gallon metal buckets with water and taken to shore for processing. Organisms which were dislodged from the artificial substrates and caught on the screen of the wash bucket were removed with forceps and added to the sample container. Trailing vegetation such as filamentous algae and macrophytes were not considered a part of the substrate sample and were removed and placed in separate sample bottles.

The rocks were removed from the baskets on shore and brushed clean of organisms and sediment depositions. This material was poured through a No. 30 U.S. Standard sieve, washed, and placed in an appropriately labelled bottle. The samples were preserved with a two-tenths (0.2) percent rose bengal solution in 80 percent isopropyl alcohol. All samples were taken to the laboratory for picking and sorting.

Incubation Periods of Artificial Substrates -
Artificial substrate samplers for periphyton and benthic macroinvertebrates were set for the spring survey during the period 30 April 1975 - 4 May 1975. Samplers were collected during the period 11-17 June 1975 yielding an incubation period of 43 to 49 days. Exact length of incubation periods are given on appropriate tables in the subsequent results and discussion sections. Between these time periods, during 13-24 May 1975, the actual field survey was conducted for water chemistry analysis and sampling of natural substrates for biota.

Samplers were set on 17 September 1975 for the fall survey. These were collected during the period 26 October - 6 November 1975 allowing an incubation period of 45 to 50 days. Exact length of incubations are given on appropriate tables in subsequent results and discussion sections.

## SECTION VI

## CHEMISTRY

### ANALYTICAL PROCEDURES

#### Aqueous Phase

In order to evaluate the impact of the AAP on the receiving waters, an extensive characterization of the water quality of the receiving stream, as well as a characterization of the industrial effluents, was undertaken. The parameters monitored included the following:

| | |
|---|---|
| Dissolved Oxygen | Suspended Solids |
| pH | Total Solids |
| Alkalinity | Chloride |
| Specific Conductance | Sulfate |
| Biological Oxygen Demand | Sodium |
| Chemical Oxygen Demand | Potassium |
| Total Organic Carbon | Hardness |
| Cadmium | Nitrate - N |
| Chromium | Nitrite - N |
| Iron | Ammonia - N |
| Lead | Kjeldahl - N |
| Manganese | Total Phosphorus |
| Mercury | Munitions Compounds |

General Water Quality Parameters -
Sampling of the aqueous phase for these parameters has been described in a previous section of this report. However, some additional comments are noteworthy here. All sample containers had been acid-washed and

rinsed with copious amounts of distilled water. As noted earlier, samples for metal anlaysis were preserved with reagent grade nitric acid. Samples for nutrient, COD, and TOC analysis were preserved with reagent grade sulfuric acid and refrigerated. All other samples were preserved by refrigeration at 4°C from the time of sampling to the completion of analysis in the laboratory.

In general, all methods of chemical analysis employed in the characterization of aqueous samples were taken from the three most widely accepted compilations of such procedures [9, 10,11]. Where methods were unavailable or insufficient to provide the desired information,(NG, NDPA, and low concentrations of metal ions), alternate analytical procedures were employed after their accuracy and precision had been statistically verified. A brief synopsis of the analytical methodology is contained in the following paragraphs.

Measurements of dissolved oxygen were made, both in the _in situ_ stream determinations and in the analysis of biochemical oxygen demand, with a polarographic-type gas sensing probe which utilizes a semipermeable fluorocarbon membrane. Hydrogen ion concentration was measured with a glass membrane/calomel combination electrode and digital pH meter capable of 0.01 unit resolution. This apparatus was also used in the standard acid titration for alkalinity. Chloride ion concentration was determined by a method adapted from the fluoride ion selective electrode method listed in the EPA manual [10]. A chloride ion selective electrode from Corning Scientific Instruments (model 476126) was used in conjunction with a silver/silver chloride reference electrode. The reference cell was fitted with a secondary salt-bridge containing 1.0 M potassium nitrate to prevent chloride bleed into the sample solution. Calibration of the device was accomplished by standard addition in order to compensate for matrix and temperature effects. Sulfate ion concentration was determined by the barium sulfate suspension technique outlined in the EPA reference [10]. Suspended solids were measured using Millipore AP40

glass fiber mats, pressure filtration and drying to constant weight at 105°C. Total solids were measured by evaporating a 100 ml aliquot of sample to dryness at 105°C.

Biological oxygen demand in the AAP water samples was measured according to the serial dilution procedure specified in APHA Standard Methods The samples were set on the same day as collected, and incubated for five days. Chemical oxygen demand was determined by the dichromate/sulfuric acid digestion method. The oxidant was 0.025 N dichromate, providing an effective detection limit of approximately 5 mg/l. Consumption of the oxidant was measured spectrophotometrically. Total organic carbon was determined using an Oceanography International total carbon system. With this system, an aliquot of acidified sample is sealed in a 10 ml ampule containing persulfate and digested overnight in a pressure vessel at 175°C. The persulfate oxidizes the organic carbon to $CO_2$. The ampules are broken and the $CO_2$ flushed through an infra-red detector interfaced with a digital integrator.

Nitrogen was measured in four forms in the aqueous phase. Nitrate - nitrogen was reacted with brucine sulfate in acidic media to produce a colored complex which was measured spectrophotometrically. Nitrate-nitrogen was similarly determined, though in this case the colored complex results from the diazo coupling of sulfanilic acid and naphthylamine hydrochloride in the presence of nitrite and excess hydrogen ions. Reduced nitrogen forms were determined by the Kjeldahl method. This method employs a mercury catalyzed sulfuric acid digestion followed by distillation into boric acid and a potentiometric endpoint titration. Ammonia concentrations were measured with a potentiometric-type gas sensing probe. Determination of ammonia with this device is now an accepted EPA procedure [10]. Evaluation of the ammonia probe by the U.S. Environmental Protection Agency and by exhaustive tests in our own laboratory reveals it to be equal in accuracy and precision to the indophenol blue method commonly employed for low levels of ammonia.

Total phosphorus levels in the aqueous phase were determined on the whole-water samples after a persulfate/sulfuric acid digestion. The digestate was subjected to analysis using either the ascorbic acid or vanadomolybdophosphoric acid technique outlined in the APHA water analysis manual, depending on the phosphorus level.

Metal analysis of the aqueous phase was accomplished by atomic absorption spectrophotometry. Total concentrations of the metals cadmium, chromium, iron, lead, manganese, and mercury were determined in the acidified water samples. Calcium and magnesium were determined on filtered water samples. High temperature flameless AAS was employed for all metals except calcium, iron, magnesium, and mercury [12]. Mercury was analyzed using the cold vapor atomic absorption technique developed by Hatch and Ott [13]. Calcium, iron and magnesium were analyzed using conventional air-acetylene flame AAS [10]. Calcium and magnesium values so determined were used to calculate hardness . The method of standard addition was utilized whenever necessary to compensate for matrix effects on instrument calibration. Sodium and potassium were determined by flame emission spectrophotometry.

Munitions Compounds -

Because the assessment of the RAAP was designed to focus on the effects of discharges from NG Area Number Two, nitroglycerin (NG) was the primary concern in developing the methodology for munitions compounds analysis. The solubility of nitroglycerin in water at 20°C is 1730 mg/l so the possibility existed for finding appreciable quantities dissolved in the aqueous phase.

Nitroglycerin (glycerol trinitrate) hydrolyzes slowly at neutral pH, and more rapidly under basic conditions, to yield mono- and dinitrates. Hercules Corporation analyses for nitroglycerin in RAAP wastewater have detected two isomeric glyceryl dinitrates at about one-third to one-half the concentration of nitroglycerin. However, unavailability of standards

precluded the identification by ENCOTEC of nitroglycerin hydrolysis products in samples from the RAAP at this time.

A second compound, nitrodiphenylamine (NDPA) was found to be a major solute in I-22 samples. NDPA is used as a stablizer in some explosive formulations. Therefore, it was decided to also look for NDPA in water and sediment samples from the RAAP. Because NDPA was not identified as a potential problem at the RAAP until the study was well underway, the determination of NDPA in all samples was not feasible. The high pressure liquid chromatographic method used for nitroglycerin was suitable for measuring the high levels of NDPA found at outfall 22, but low levels of NDPA could not be detected by this method under the conditions used for nitroglycerin analysis. Therefore selected river sediment samples were re-analyzed for NDPA by a gas chromatographic method.

Samples were collected in four liter brown glass bottles and iced on site. After return to the field laboratory, a 50 ml aliquot of benzene was added and the sample stirred with a teflon and glass "T" stirrer for 10-15 minutes. The bottles were sealed with the benzene inside and transported back to Ann Arbor. There the benzene was drawn off and each sample was subsequently extracted with two additional aliquots of benzene. I-22 samples that had high levels of NDPA were extracted with additional aliquots of benzene until no orange color was visible in the extract. The combined benzene extracts were dried by passage through anhydrous sodium sulfate and then reduced in volume to approximately 5 ml by warming on a water bath with simultaneous passage of nitrogen over the liquid surface.

This concentrate was then applied to the top of a 1.0 cm by 7.0 cm high column of Davison Grade 923 silica gel. The column was wet packed in benzene. One hundred ml of 20 percent (v/v) ethyl ether in benzene was used to elute the components of interest. The eluant was evaporated

nearly to dryness and transferred to a 5 ml or 12 ml vial. Before analysis, the solvent was completely removed and the residue was redissolved in a known volume of benzene. The final volume varied depending on anticipated concentration of NDPA and NG, but it was always greater than or equal to 1 ml. It was found that NDPA could be lost from the sample extract during the final evaporation step. Therefore, care was taken to always maintain a small volume of solvent while processing a sample for NDPA analysis. Using this procedure, the recovery of NDPA from a 20 gram sediment sample spiked with 0.0027 grams of NDPA was 91%.

A method was needed to quantify trinitroglycerin (NG) and o-nitrodiphenylamine in the organic extracts of the water and sediment samples. NG presented something of a problem due to its chemical and thermal instability. Methods previously used included wet chemistry [14], gas chromatography [15,16], and liquid chromatography[17]. Gas chromatography depends essentially on a constant rate of decomposition in the injector, column and detector and is thus extremely sensitive to variations in temperature, flow rate and possible catalytic effects of unknown magnitude from other chemical compounds. High pressure liquid chromatrography suffers from a lack of sensitivity if run at the standard 255 nm wave length (i.e. the molar extinction coefficient for NG is quite small at this wavelength). Using a variable wavelength detector set at 215 nm and 1 cm cells, however, the sensitivity was improved markedly. Using standard solutions, a lower detection limit of about 10 ppm was established. Since the workup of the field samples involved solvent extraction and concentration, much lower concentrations could be measured in the natural samples. Analytical conditions were:

| | |
|---|---|
| Detector - | u.v. at 215 nm |
| Eluant - | 10% dioxane in hexane (u.v. grade) |
| Flow rate - | 2 ml/min |
| Column - | ¼" x 1' (30.5 cm) ss packed with Microporasil (Water Associates). |

Under these conditions, retention times were:

| | |
|---|---|
| o-NDPA | 3.0 min. |
| 2,4,6,-TNT | 5.0 min. |
| 1,3,5,-TNB | 6.7 min. |
| NG | 10.5 min. |

Chromatograms of mixed standards and an organic extract are shown in Figures 4 and 5 . The poor resolution of benzene, NDPA, and other non-polar species prevents accurate identification and quantification of low levels of NDPA.

Several unidentified peaks were also detected in the organic extracts of RAAP samples and it was therefore necessary to verify that peaks with retention times matching those of NDPA and NG were indeed the compounds in question. For NG a thin layer chromatographic method was developed (See Figure 6 ). The organic concentrate and a standard were spotted on a silica gel plate (Silica Gel IB-F, J.T. Baker) and developed with benzene. The plates were dried and sprayed with a color-developing agent consisting of equal volumes of the sulfanilic acid and naphthylamine hydrochloride reagents solutions used in APHA Standard Methods (p 241) for nitrite determinations. The plates are placed in a 105°C oven for three to four minutes, at which time nitroglycerin spots are yellow-orange in color. Plates discolored in eight to ten hours.

For NDPA most analyses were made by gas chromatography. Conditions used were:

| | |
|---|---|
| Column - | 1/8" o.d. x 6' s.s. packed with 5 percent Dexsil 300 on 80/100 HPCW |
| Detector - | flame ionization |
| Flow rate - | 50 ml/min $N^2$ |
| Injector temp. - | 250°C |
| Temperature program - | one minute at 115°C, 30°C/per minute 115°-250°C, isothermal at 250°C for 5 minutes |

FIGURE 4 High Pressure Liquid Chromatogra[m] Mixed Standard 100 mg/l Each Component

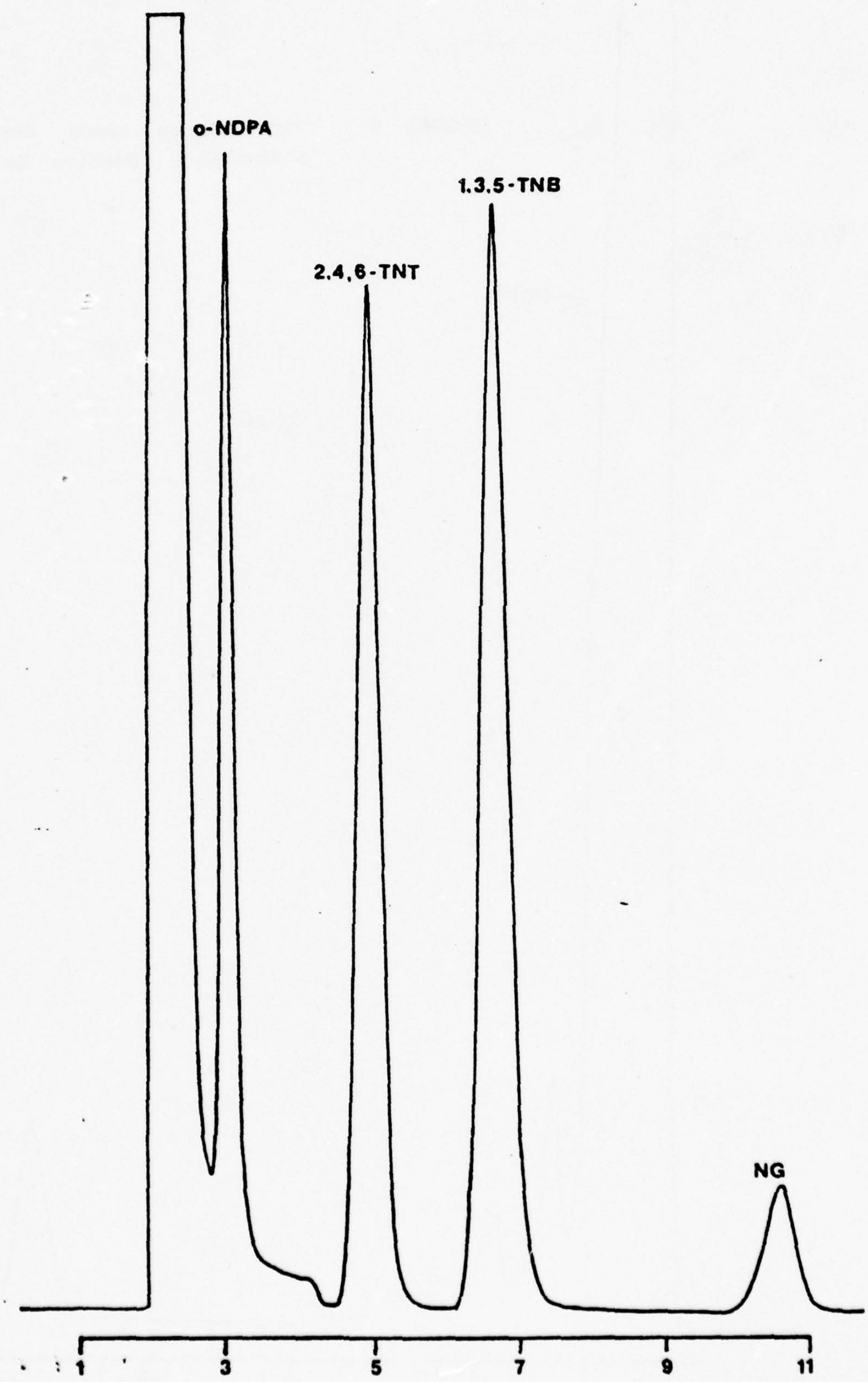


FIGURE 5 High Pressure Liquid Chromatogram
Station R-5 Benzene Extract

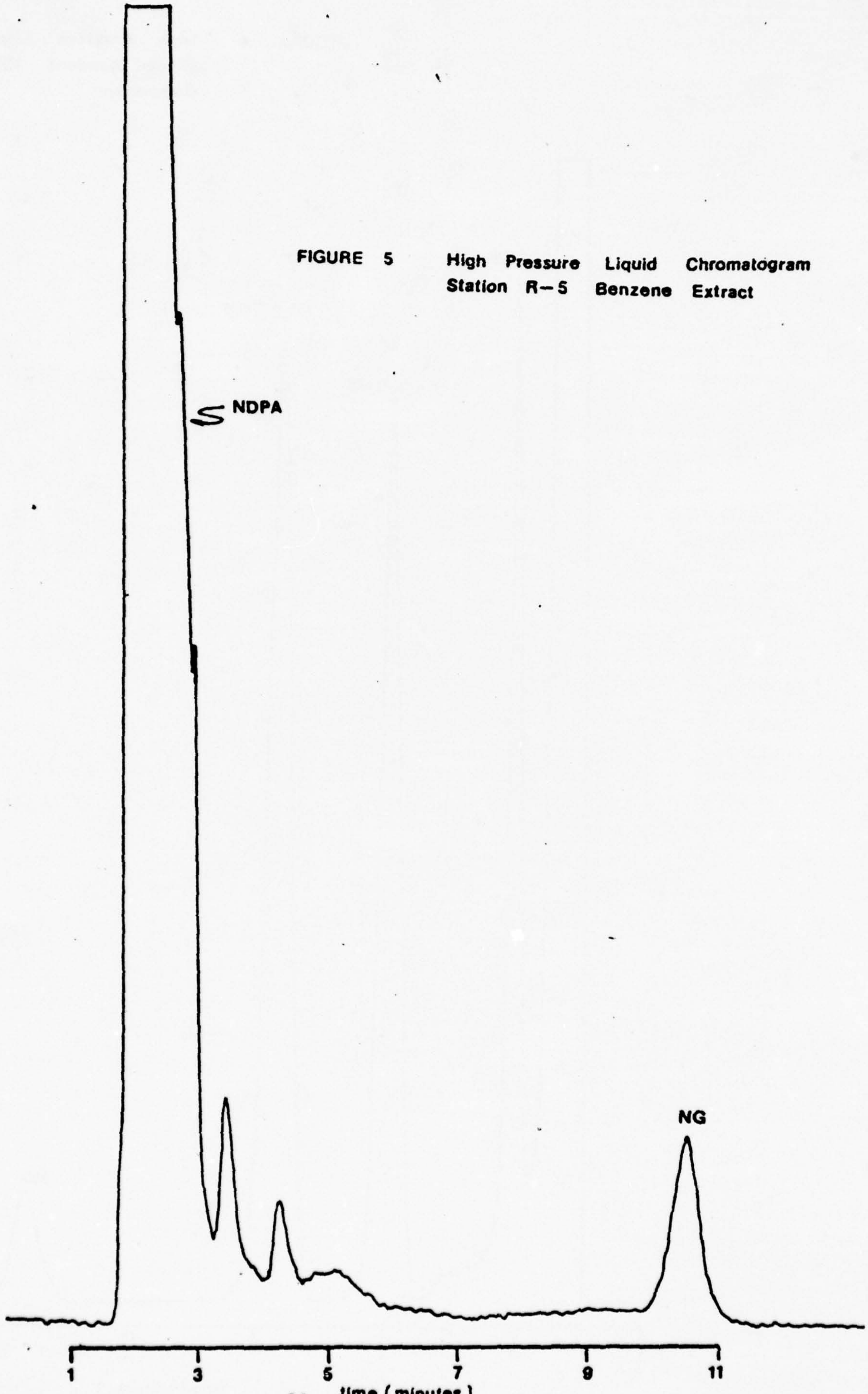
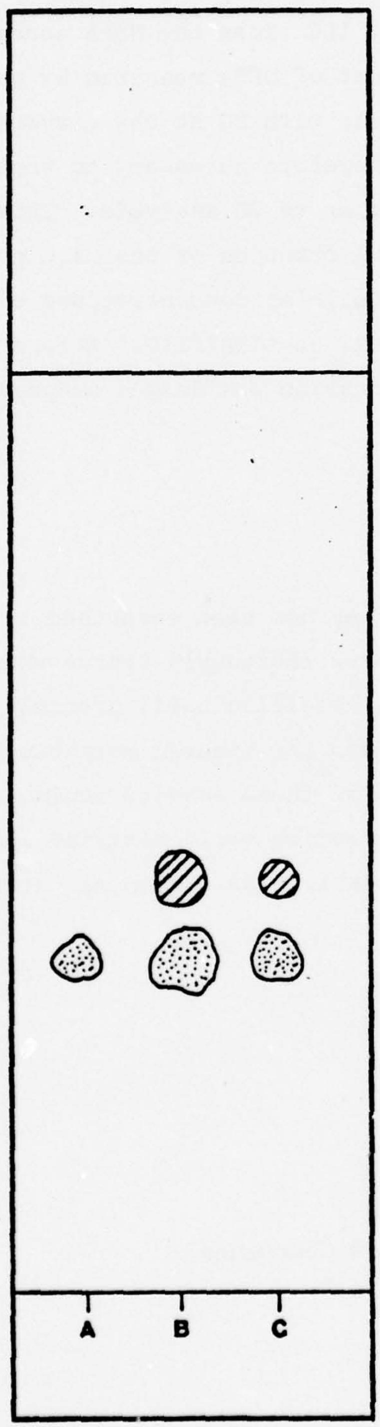


FIGURE 6 Thin Layer Chromatographic Identification of Munitions Compounds




Key: A - River Station R-6 Sediment Core 1 May 1975

B - Mixed Standard
o-NDPA RF: 0.47
Glycerol Trinitrate RF: 0.40

C - River Station R-5 Sediment Core 3, May 1975

— Appeared yellow under visible light.

— Colorless; turns red when sprayed with color reagent

Under these conditions, NDPA had a retention time of 512 seconds. Chromatograms of a NDPA standard and a sample extract are shown in Figures 7 and 8.

High levels of trinitroglycerin (i.e., 100 times the NDPA concentration) have the effect of decreasing the amount of NDPA measured by gas chromatography, apparently because NDPA reacts with NG at the elevated temperatures found in the column. It was therefore necessary to separate NDPA from the NG present in I-22 samples prior to GC analysis. This separation was accomplished by collecting the NDPA fraction of the high pressure liquid chromatography eluent. When equimolar concentrations of NG and NDPA were administered to the GC column, no significant interaction was observed. For this reason, prior separation was deemed unnecessary for river sediment extracts.

## Sediment Phase

Sampling of the sediment phase at the AAP has been described in an earlier section of this report. The samples were thoroughly frozen when received from the field and were stored in this condition until processing commenced. Freezing sediment material often disrupts the mineral morphology, but it was felt that the analyses to be performed on these samples would not be adversely affected and the low temperature preservation would minimize the decomposition of any munitions-related compounds present. The following parameters were determined on the sediment samples:

| | |
|---|---|
| Total Solids | Cadmium |
| Total Volatile Solids | Chromium |
| Chemical Oxygen Demand | Iron |
| Hexane Extractable | Lead |
| Kjeldahl Nitrogen | Manganese |
| Nitrate Nitrogen | Mercury |
| Total Phosphorus | Munitions Compounds |

**FIGURE 7** Gas Chromatogram NDPA Standard

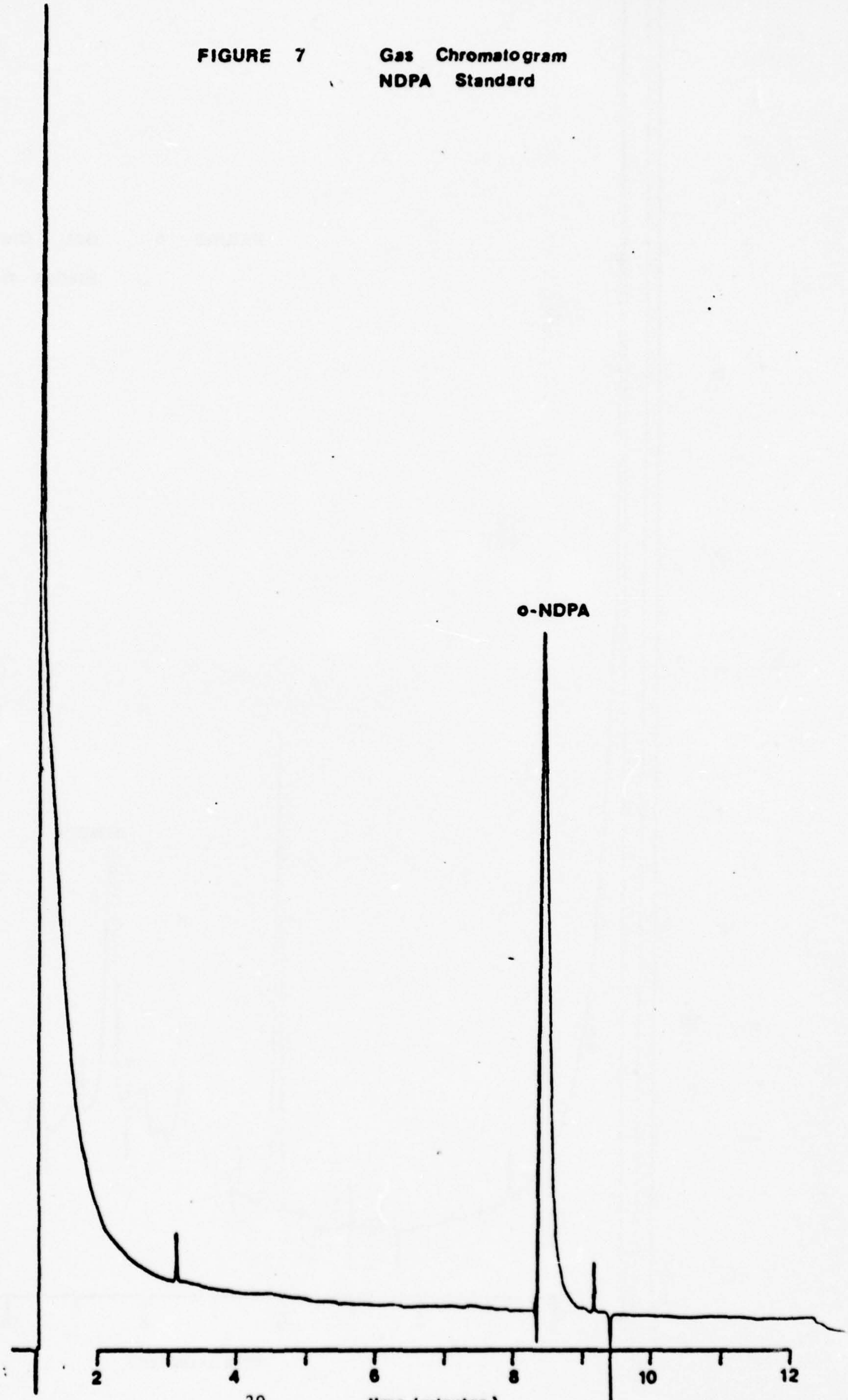
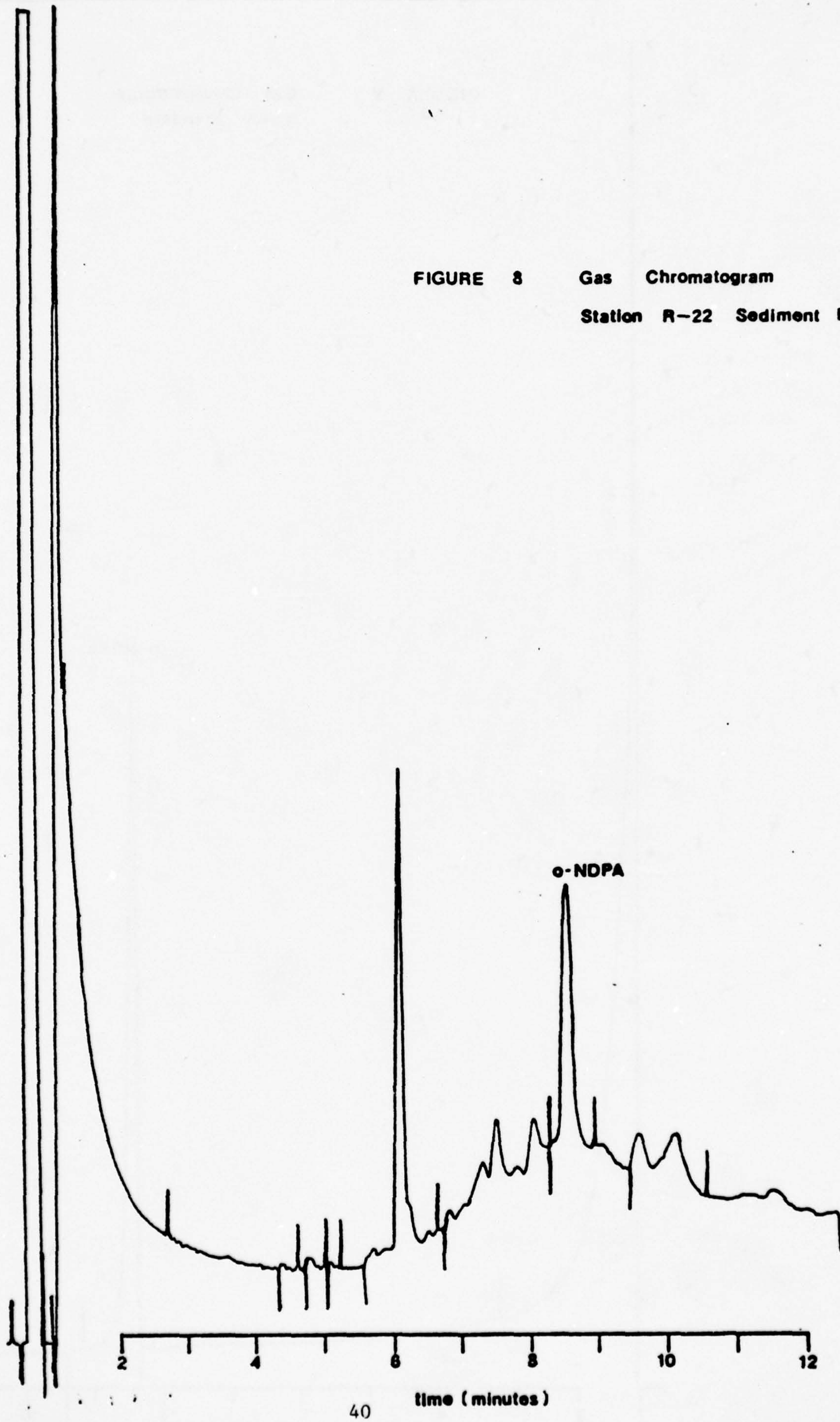


FIGURE 8 Gas Chromatogram
Station R-22 Sediment Extract



General Sediment Parameters -

The sediment samples were thawed for processing and extruded from the polycarbonate core liners. Physical descriptions were made immediately and the core samples were sectioned according to depth from the water/sediment interface. For the present study, the upper 10 cm section was isolated, weighed and dried to constant weight at 50°C. Where cores from the first survey were of sufficient depth, a 10-20 cm section was also isolated and processed. After dry weights were recorded, all sediment samples were ground with a mortar and pestle and sieved through a 20 mesh screen (particles $>$ 841 micrometers). The weight fraction retained by the sieve was recorded and this fraction was excluded from the chemical analyses. Methods of chemical analysis for sediment characterization were taken primarily from the EPA reference "Chemistry Laboratory Manual: Bottom Sediments" [18]. A brief description of the procedures employed follows.

The analysis of carbonaceous material in the sediments include the determination of COD using the potassium dichromate-sulfuric acid digestion method. Volatile solids were determined by ashing the samples at 575°C for four hours. Hexane extractable materials were also determined in the dried sediment. Hexane served as the solvent in a four hour soxhlet extraction. The hexane was evaporated from the final extract and the residue was measured gravimetrically[18].

Reduced nitrogen forms in the sediment phase were determined by the Kjeldahl digestion/distillation/titration technique. Nitrate was analyzed as an indicator of oxidized nitrogen forms. In this analysis the nitrate was leached from the sediment by refluxing in dilute acid media. The leachate was then filtered and reacted with brucine sulfate under the controlled temperature conditions of the brucine method. The resultant colored complex was related spectrophotometrically to known standards. The third major biological nutrient, phosphorus, was measured in the sediments with the vanadomolybdophosphoric acid test after the samples had undergone a persulfate/sulfuric acid digestion [18].

Sediment samples for metal analysis, with the exception of mercury, were prepared by dry ashing at 575°C for four hours, acid leaching the residue with a nitric acid/hydrogen peroxide solution, and removing the undissolved residue by filtration. The filtrate was analyzed for cadmium, chromium, iron, lead, and manganese using conventional air-acetylene flame atomic absorption spectrophotometry[19]. Mercury analysis was performed on samples prepared by wet digestion[20]. The finely divided samples were allowed to react overnight with fuming nitric acid and potassium dichromate. After digestion was complete, the excess dichromate was reduced with hydroxylamine hydrochloride. Reduction of the mercury with stannous chloride was followed by detection of the resulting elemental mercury using the cold vapor atomic absorption method[13].

Munitions Compounds -

Twenty grams of previously dried sediment sample was soxhlet extracted for four hours with benzene. Clean-up and analysis followed the same procedure outlined in the water chemistry methodology.

## RESULTS

Because of the large volume of chemical information generated during this study, only summaries of aqueous phase chemistry data are included in this section of the report. A complete compilation of the aqueous phase data can be found in Appendices II through IV. All sediment phase chemistry data is included in this section. Data for nitroglycerin and another munitions compound, NDPA, are presented and discussed in a separate part of this section.

The aqueous phase data has been condensed into tables showing the mean value, the minimum value, and the maximum value found during a survey period of each parameter. When calculating the mean value for a group of samples where one or more of the samples had a concentration which was less than the detection limit, the sample was treated as if it contained a concentration equal to the detection limit. If all the samples of a station contained undetectable amounts of a parameter, the mean was reported as less than the detection limit.

### General Chemistry Data

#### Aqueous Phase -

A summary of the aqueous phase chemistry data is presented in Tables 2 - 13. The mean value, maximum value, and minimum value found at a station during each survey is shown for every parameter that was measured. A complete compilation of this data can be found in Appendices II and III.

Industrial outfalls - To assess the potential impact of the industrial outfalls, a knowledge of flow rates is necessary. Information on daily discharge rates from each outfall was available from RAAP personnel and NPDES permit monitoring reports, and flow measurements were made as part

of both the May and October sampling programs. This data is summarized in Table 1.

Table 1 . RADFORD ARMY AMMUNITION PLANT
INDUSTRIAL DISCHARGES

| Outfall | Units | May | October | RAAP Data* |
|---|---|---|---|---|
| 18 | liters/minute | 198 | 276 | 244 |
| 19 | liters/minute | 36 | 38 | 93 |
| 20 | liters/minute | 4 | 19 | 19 |
| 21 | liters/minute | ** | ** | ** |
| 22 | liters/minute | 3 | 3 | 11 |
| Total | | 241 | 336 | 367 |

*Data obtained was in gallons/day. Conversion to liters/minute was made on the assumption that lines were running only 8 hours per day.
**Wash down water. RAAP data indicates 8127 liters used per day.

Note that Outfalls 18 and 19 account for more than 90% of the total flow. Both these outfalls enter the New River between stations R2 and R3.

A scan of the chemical data for Outfalls I-18 through I-22, (Tables 2 through 6 ), reveals high levels of carbonaceous material, minerals, oxidized, and to a lesser extent reduced, nitrogen forms, and in some cases lead. The hydrogen ion concentrations in outfalls I-19 and I-20 are quite low, (median pH = 10.4 and 10.6 respectively), and slightly low at I-18 and I-21.

Total organic carbon (TOC), chemical oxygen demand (COD), and usually biochemical oxygen demand (BOD) in the outfall samples are ten to one hundred times the levels found in the river. Frequently BOD results are relatively low compared to COD and TOC results for the same sample, indicating an inhibitory agent in the waste water.

Table 2. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 18

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 4090 | 5800 | 900 | 5940 | 6900 | 4880 |
| Total Solids | mg/l | 4570 | 5690 | 2040 | 6060 | 6810 | 4650 |
| Total Suspended Solids | mg/l | 17 | 21 | 10 | 14 | 18 | 10 |
| pH | SU | 8.90* | 9.50 | 8.50 | 9.10* | 9.45 | 8.65 |
| Total Alkalinity | mg/l as $CaCO_3$ | 600 | 1060 | 390 | 636 | 951 | 339 |
| Chloride | mg/l | 24.2 | 34.4 | 15.0 | 35.4 | 41.2 | 25.2 |
| Sulfate | mg/l | 62 | 76 | 40 | 107 | 123 | 94 |
| Total Hardness | mg/l as $CaCO_3$ | 42 | 49 | 23 | 35 | 41 | 27 |
| Calcium | mg/l | 9.8 | 12.6 | 2.2 | 7.5 | 9.3 | 3.4 |
| Magnesium | mg/l | 4.2 | 4.3 | 4.0 | 4.1 | 4.6 | 3.8 |
| Sodium | mg/l | 1290 | 1580 | 580 | 1730 | 1970 | 1360 |
| Potassium | mg/l | 7.4 | 7.9 | 5.8 | 8.7 | 9.1 | 7.9 |
| Dissolved Oxygen | mg/l | 8.5 | 9.0 | 8.1 | 9.4 | 10.0 | 8.9 |
| BOD | mg/l | 7 (1/4) | 14 | <1 | 2 | 4 | 1 |
| COD | mg/l | 90 | 134 | 30 | 121 | 163 | 98 |
| TOC | mg/l | 49 | 54 | 46 | 42 | 47 | 38 |
| Kjeldahl-N | mg/l | | < 0.2 | | 0.2 (4/5) | 0.5 | <0.1 |
| Ammonia-N | mg/l | 0.098 | 0.13 | 0.069 | 0.10 | 0.13 | 0.090 |
| Nitrite-N | mg/l | 0.26 | 0.36 | 0.19 | 0.38 | 0.51 | 0.22 |

Table 2. Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Nitrate-N | mg/l | 670 | 970 | 180 | 840 | 910 | 730 |
| Total Phosphorus | mg/l | 0.006 | 0.010 | 0.003 | 0.002 | 0.004 | 0.001 |
| Cadmium | mg/l | 0.0002 (2/5) | 0.0004 | <0.0001 | | <0.0001 | |
| Chromium | mg/l | 0.061 | 0.122 | 0.019 | 0.003 | 0.004 | 0.002 |
| Iron | mg/l | 0.11 | 0.21 | 0.066 | 0.098 | 0.12 | 0.067 |
| Lead | mg/l | 0.730 | 2.5 | 0.082 | 0.034 | 0.11 | 0.010 |
| Manganese | mg/l | 0.002 | 0.003 | 0.001 | 0.007 | 0.011 | 0.004 |
| Mercury | mg/l | 0.013 (1/5) | 0.060 | <0.0001 | 0.0002 (3/5) | 0.0006 | <0.0001 |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/ total number of samples analyzed.

Table 3. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I19

| Parameter | Units | May 1975 | | | October 1975 | | |
|---|---|---|---|---|---|---|---|
| | | Mean | Max. | Min. | Mean | Max. | Min. |
| Specific Conductance | μmhos/cm | 6410 | 9700 | 1760 | 5540 | 12900 | 331 |
| Total Solids | mg/l | 6940 | 13300 | 1860 | 4460 | 12500 | 245 |
| Total Suspended Solids | mg/l | 22 | 35 | 6 | 21 | 54 | 1 |
| pH | SU | 10.50* | 10.75 | 10.40 | 10.30* | 10.70 | 9.60 |
| Total Alkalinity | mg/l as $CaCO_3$ | 5210 | 9430 | 1500 | 3690 | 11100 | 154 |
| Chloride | mg/l | 42.0 | 64.2 | 19.7 | 63.9 | 125 | 20.7 |
| Sulfate | mg/l | 61 | 120 | 4 | 45 | 64 | 26 |
| Total Hardness | mg/l as $CaCO_3$ | 28 | 32 | 22 | 46 | 70 | 35 |
| Calcium | mg/l | 4.5 | 6.1 | 2.9 | 3.7 | 4.4 | 2.9 |
| Magnesium | mg/l | 4.0 | 4.2 | 3.5 | 8.9 | 15.3 | 5.9 |
| Sodium | mg/l | 2910 | 5550 | 810 | 1810 | 5300 | 83 |
| Potassium | mg/l | 12 | 33 | 3.5 | 14 | 31 | 4.1 |
| Dissolved Oxygen | mg/l | 8.1 | 9.2 | 6.3 | 9.6 | 10.2 | 9.1 |
| BOD | mg/l | 75 | 183 | 14 | 30 | 67 | 1 |
| COD | mg/l | 267 | 458 | 106 | 266 | 626 | 32 |
| TOC | mg/l | 138 | 250 | 50 | 78 | 186 | 8 |
| Kjeldahl-N | mg/l | 2.0 | 4.4 | 0.3 | 2.3 (2/5) | 9.0 | <0.1 |
| Ammonia-N | mg/l | 0.50 | 1.2 | 0.12 | 0.30 | 0.97 | 0.051 |
| Nitrite-N | mg/l | 7.1 | 18 | 0.86 | 5.0 | 21 | 0.27 |
| Nitrate-N | mg/l | 160 | 440 | 20 | 59 | 170 | 2.5 |

Table 3 . Continued

| Parameters | Units | May 1975 Mean | | May 1975 Max. | May 1975 Min. | October 1975 Mean | | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/l | 0.069 | | 0.36 | 0.002 | 0.005 | (1/5) | 0.011 | <0.001 |
| Cadmium | mg/l | 0.0005 | (2/5) | 0.0011 | <0.0001 | 0.0007 | (1/5) | 0.0019 | <0.0001 |
| Chromium | mg/l | 0.007 | | 0.011 | 0.002 | 0.010 | | 0.024 | 0.002 |
| Iron | mg/l | 0.087 | | 0.16 | 0.056 | 0.038 | | 0.064 | 0.013 |
| Lead | mg/l | 0.082 | | 0.122 | 0.026 | 0.014 | (1/5) | 0.039 | <0.001 |
| Manganese | mg/l | 0.001 | | 0.002 | 0.001 | 0.004 | | 0.006 | 0.002 |
| Mercury | mg/l | 0.0013 | (2/5) | 0.0032 | <0.0001 | | | <0.0001 | |

*Mediam Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 4. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 20

| Parameter | Units | May 1975 | | | October 1975 | | |
|---|---|---|---|---|---|---|---|
| | | Mean | Max. | Min. | Mean | Max. | Min. |
| Specific Conductance | μmhos/cm | 11400 | 21000 | 3530 | 8320 | 12400 | 2110 |
| Total Solids | mg/l | 11900 | 19800 | 3180 | 7650 | 13500 | 1930 |
| Total Suspended Solids | mg/l | 29 | 46 | 9 | 17 | 30 | 4 |
| pH | SU | 10.50* | 10.60 | 10.30 | 10.70* | 10.80 | 10.20 |
| Total Alkalinity | mg/l as $CaCO_3$ | 9380 | 16430 | 2570 | 6120 | 9830 | 1560 |
| Chloride | mg/l | 55.3 | 87.2 | 28.9 | 112 | 163 | 27.3 |
| Sulfate | mg/l | 130 | 300 | 29 | 63 | 208 | 16 |
| Total Hardness | mg/l as $CaCO_3$ | 29 | 32 | 25 | 33 | 47 | 23 |
| Calcium | mg/l | 5.1 | 6.2 | 3.8 | 2.4 | 3.7 | 1.1 |
| Magnesium | mg/l | 4.0 | 4.2 | 3.7 | 6.5 | 10.7 | 3.7 |
| Sodium | mg/l | 5060 | 8400 | 1360 | 3320 | 5350 | 830 |
| Potassium | mg/l | 26 | 43 | 7.3 | 20 | 30 | 6.7 |
| Dissolved Oxygen | mg/l | 5.3 | 6.9 | 3.2 | 9.2 | 9.8 | 8.7 |
| BOD | mg/l | 628 | >2250 | 114 | 59 | 142 | 23 |
| COD | mg/l | 1790 | 4060 | 527 | 491 | 1120 | 130 |
| TOC | mg/l | 380 | 860 | 120 | 148 | 278 | 43 |
| Kjeldahl-N | mg/l | 5.0 | 8.2 | 1.5 | 3.5 | 6.1 | 1.4 |
| Ammonia-N | mg/l | 1.1 | 2.1 | 0.25 | 0.41 | 0.70 | 0.14 |
| Nitrite-N | mg/l | 15 | 34 | 3.3 | 8.5 | 16 | 0.32 |
| Nitrate-N | mg/l | 96 | 230 | 0.18 | 130 | 340 | 23 |

Table 4 . Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/l | 0.012 | 0.022 | 0.002 | 0.003 | (3/5)0.006 | <0.001 |
| Cadmium | mg/l | 0.0010 | 0.0026 | 0.0002 | 0.0001 | (3/5)0.0002 | <0.0001 |
| Chromium | mg/l | 0.012 | 0.026 | 0.003 | 0.004 | 0.008 | 0.002 |
| Iron | mg/l | 0.078 | 0.14 | 0.048 | 0.083 | 0.23 | 0.021 |
| Lead | mg/l | 0.070 | 0.124 | 0.026 | 0.016 | 0.025 | 0.002 |
| Manganese | mg/l | 0.002 | 0.004 | 0.001 | 0.006 | 0.012 | 0.003 |
| Mercury | mg/l | 0.0006 | (2/5) 0.0018 | <0.0001 | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 5. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I 21

| Parameter | Units | May 1975** Mean | May 1975** Max. | May 1975** Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 342 | - | - | 624 | 1020 | 376 |
| Total Solids | mg/1 | 488 | - | - | 1240 | 1450 | 796 |
| Total Suspended Solids | mg/1 | 69 | - | - | 510 | 1100 | 271 |
| pH | SU | 9.52* | - | - | 9.10* | 9.90 | 8.00 |
| Total Alkalinity | mg/1 as $CaCO_3$ | 108 | - | - | 414 | 682 | 200 |
| Chloride | mg/1 | 18.3 | - | - | 30.2 | 54.2 | 15.9 |
| Sulfate | mg/1 | 23 | - | - | 78 | 148 | 52 |
| Total Hardness | mg/1 as $CaCO_3$ | 42 | - | - | 118 | 194 | 36 |
| Calcium | mg/1 | 10.1 | - | - | 10.0 | 29.9 | 0.9 |
| Magnesium | mg/1 | 4.1 | - | - | 22.7 | 29.0 | 8.2 |
| Sodium | mg/1 | 36.1 | - | - | 145 | 305 | 6.9 |
| Potassium | mg/1 | 18 | - | - | 12 | 20 | 2.6 |
| Dissolved Oxygen | mg/1 | 7.1 | - | - | 9.7 | 10.1 | 9.4 |
| BOD | mg/1 | 86 | - | - | 90 | 145 | 7 |
| COB | mg/1 | 258 | - | - | 652 | 1100 | 361 |
| TOC | mg/1 | 190 | - | - | 66 | 106 | 8 |
| Kjeldahl-N | mg/1 | 4.5 | - | - | 8.6 | 13.7 | 4.4 |
| Ammonia-N | mg/1 | 0.33 | - | - | 0.17 | 0.27 | 0.043 |
| Nitrite-N | mg/1 | 0.35 | - | - | 0.10 | 0.23 | 0.010 |
| Nitrate-N | mg/1 | 25 | - | - | 18 | 23 | 12 |

Table 5. Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/1 | 0.28 | - | - | 0.098 | 0.16 | 0.009 |
| Cadmium | mg/1 | 0.0007 | - | - | 0.0001 (1/4) | 0.0002 | <0.0001 |
| Chromium | mg/1 | 0.010 | - | - | 0.007 | 0.009 | 0.004 |
| Iron | mg/1 | 0.15 | - | - | 0.19 | 0.20 | 0.097 |
| Lead | mg/1 | 0.96 | - | - | 1.1 | 1.4 | 0.78 |
| Manganese | mg/1 | 0.013 | - | - | 0.021 | 0.031 | 0.008 |
| Mercury | mg/1 | 0.0001 | - | - | | <0.0001 | |

* Median Value

** Sampled only once.

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 6. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
INDUSTRIAL STATION I22

| Parameter | Units | May 1975 | | | October 1975 | | |
|---|---|---|---|---|---|---|---|
| | | Mean | Max. | Min. | Mean | Max. | Min. |
| Specific Conductance | μmhos/cm | 216 | 311 | 142 | 332 | 397 | 298 |
| Total Solids | mg/l | 313 | 439 | 225 | 586 | 763 | 420 |
| Total Suspended Solids | mg/l | 8 | 12 | 1 | 22 | 66 | 6 |
| pH | SU | 7.70* | 9.20 | 6.55 | 7.90* | 8.40 | 7.60 |
| Total Alkalinity | mg/l as $CaCO_3$ | 101 | 165 | 66 | 134 | 156 | 100 |
| Chloride | mg/l | 9.7 | 13.2 | 5.9 | 12.4 | 15.4 | 8.6 |
| Sulfate | mg/l | 38 | 72 | 10 | 34 | 52 | 20 |
| Total Hardness | mg/l as $CaCO_3$ | 44 | 58 | 37 | 236 | 266 | 175 |
| Calcium | mg/l | 10.7 | 14.0 | 8.8 | 53.6 | 62.0 | 37.3 |
| Magnesium | mg/l | 4.3 | 5.6 | 3.7 | 25.0 | 27.0 | 19.9 |
| Sodium | mg/l | 53.2 | 84.8 | 34.8 | 22.4 | 31.5 | 9.5 |
| Potassium | mg/l | 4.2 | 4.7 | 3.4 | 4.1 | 4.9 | 3.3 |
| Dissolved Oxygen | mg/l | 9.0 | 9.8 | 8.1 | 10.4 | 11.8 | 9.4 |
| BOD | mg/l | 295 | 455 | 101 | 419 | 538 | 203 |
| COD | mg/l | 730 | 1350 | 215 | 1160 | 1670 | 720 |
| TOC | mg/l | 195 | 280 | 64 | 334 | 479 | 217 |
| Kjeldahl-N | mg/l | 3.2 | 4.1 | 1.9 | 3.3 | 4.2 | 2.4 |
| Ammonia-N | mg/l | 0.10 | 0.12 | 0.074 | 0.14 | 0.19 | 0.11 |
| Nitrite-N | mg/l | 0.76 | 2.8 | 0.031 | 0.86 | 2.3 | 0.23 |
| Nitrate-N | mg/l | 57 | 84 | 33 | 67 | 100 | 36 |

Table 6. Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/1 | 0.20 | 0.46 | 0.038 | 0.004 | (3/4) 0.011 | <0.001 |
| Cadmium | mg/1 | 0.0003 | 0.0006 | 0.0002 | 0.0007 | 0.0014 | 0.0003 |
| Chromium | mg/1 | 0.009 | 0.024 | 0.001 | 0.002 | 0.003 | 0.001 |
| Iron | mg/1 | 0.097 | 0.26 | 0.060 | 0.085 | 0.10 | 0.046 |
| Lead | mg/1 | 2.0 | 2.7 | 1.4 | 68 | 230 | 8.1 |
| Manganese | mg/1 | 0.011 | 0.021 | 0.005 | 0.046 | 0.090 | 0.018 |
| Mercury | mg/1 | 0.0006 | 0.0010 | 0.0001 | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Total solids concentrations in Outfalls I-18, I-19, and I-20 range from 200 mg/l to 20,000 mg/l, but in general fall within the range 4,000 - 12,000 mg/l. This is approximately one hundred times the solids level found in the river. Most of the solids are dissolved soda ash ($Na_2CO_3$) used for neutralization and alkaline washes. The concentrations of other mineral ions ($Ca^{++}$, $Mg^{++}$, $K^+$, $Cl^-$, and $SO_4^{--}$) are comparable to the levels found in the river.

Though phosphorus inputs from the NG #2 Area at the RAAP are negligible, nitrogen loads are great enough to have a significant localized impact on the New River. Most of the nitrogen is in the form of nitrate. The highest nitrate levels are found in Outfall I-18 samples, averaging 670 mg/l as nitrogen during the May survey and 840 mg/l during the October survey. Because Outfall I-18 also discharges the largest volume of water, it carries approximately 95% of all the nitrate from the NG #2 Area.

All outfalls carry levels of cadmium, chromium, mercury, and lead which are slightly higher than those found in the receiving waters. Lead levels are especially high in Outfall I-22, (230 mg/l maximum), and to a lesser extent in Outfall I-18, (the average during the first survey was 0.73 mg/l). This lead input shows up in the sediments around Outfall I-22.

River stations - River aqueous phase chemistry data is presented in Tables 7 through 13. Appendix III contains all the individual analytical results.

There was a noticeable shift in river water characteristics between the May survey and the October survey. In May the pH, alkalinity, hardness, and total solids were higher than in October, and total suspended solids were lower. While several factors upstream of the study area may play a part in this change, including the limnology of Claytor Reservoir, the May water quality appears to be more characteristic of ground water, while the October water quality is more characteristic of run-off.

Table 7. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R1
(DAY)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 65 | 72 | 56 | 58 | 68 | 50 |
| Total Solids | mg/l | 90 | 103 | 72 | 76 | 83 | 67 |
| Total Suspended Solids | mg/l | 3 | 4 | 1 | 9 | 17 | 3 |
| pH | SU | 7.65* | 8.30 | 6.96 | 6.82* | 7.05 | 6.70 |
| Total Alkalinity | mg/l as $CaCO_3$ | 40 | 43 | 37 | 26 | 27 | 25 |
| Chloride | mg/l | 5.8 | 6.8 | 4.6 | 12.5 | 14.5 | 10.3 |
| Sulfate | mg/l | 13 | 30 | 6 | 8 | 11 | 3 |
| Total Hardness | mg/l as $CaCO_3$ | 41 | 44 | 38 | 28 | 29 | 27 |
| Calcium | mg/l | 9.8 | 11.3 | 8.7 | 5.9 | 6.1 | 5.6 |
| Magnesium | mg/l | 3.9 | 4.0 | 3.8 | 3.2 | 3.4 | 3.1 |
| Sodium | mg/l | 2.5 | 2.7 | 2.4 | 3.3 | 3.4 | 3.2 |
| Potassium | mg/l | 1.6 | 1.6 | 1.5 | 2.3 | 2.4 | 2.3 |
| Dissolved Oxygen | mg/l | 9.7 | 9.8 | 9.5 | 9.8 | 10.2 | 9.2 |
| BOD | mg/l | 2 | 2 | 1 | 2 | 3 | 2 |
| COD | mg/l | 9 (2/5) | 19 | <5 | 6 (2/4) | 9 | <5 |
| TOC | mg/l | 4 | 7 | 2 | 3 | 4 | 2 |
| Kjeldahl-N | mg/l | 0.1 | 0.2 | 0.1 | 0.4 | 0.4 | 0.2 |
| Ammonia-N | mg/l | 0.076 | 0.11 | 0.051 | 0.088 | 0.12 | 0.065 |
| Nitrite-N | mg/l | 0.002 (2/5) | 0.003 | <0.001 | 0.003 (1/4) | 0.007 | <0.001 |
| Nitrate-N | mg/l | 0.47 | 0.50 | 0.43 | 0.46 | 0.47 | 0.45 |

Table 7 . Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/1 | 0.013 | 0.021 | 0.008 | 0.014 | 0.026 | 0.007 |
| Cadmium | mg/1 | 0.0001 (1/5) | 0.0002 | <0.0001 | | <0.0001 | |
| Chromium | mg/1 | 0.004 (2/5) | 0.014 | <0.001 | 0.006 | 0.012 | 0.002 |
| Iron | mg/1 | 0.17 | 0.22 | 0.13 | 0.53 | 0.64 | 0.43 |
| Lead | mg/1 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 |
| Manganese | mg/1 | 0.025 | 0.033 | 0.016 | 0.058 | 0.074 | 0.044 |
| Mercury | mg/1 | | <0.0001 | | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 8. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R1
(Night)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | | | | 60 | 70 | 42 |
| Total Solids | mg/l | | | | 69 | 73 | 65 |
| Total Suspended Solids | mg/l | Station R1 Was Not Sampled at Night During the First Survey. | | | 5 | 8 | 2 |
| pH | SU | | | | 6.90* | 7.05 | 6.50 |
| Total Alkalinity | mg/l as $CaCO_3$ | | | | 24 | 26 | 22 |
| Chloride | mg/l | | | | 12.4 | 14.6 | 10.9 |
| Sulfate | mg/l | | | | 6 | 9 | 4 |
| Total Hardness | mg/l as $CaCO_3$ | | | | 24 | 26 | 23 |
| Calcium | mg/l | | | | 4.8 | 5.2 | 4.5 |
| Magnesium | mg/l | | | | 3.1 | 3.3 | 2.9 |
| Sodium | mg/l | | | | 3.3 | 3.4 | 3.2 |
| Potassium | mg/l | | | | 2.3 | 2.4 | 2.3 |
| Dissolved Oxygen | mg/l | | | | 9.4 | 10.0 | 9.1 |
| BOD | mg/l | | | | 2 | 2 | 2 |
| COD | mg/l | | | | 5 (3/4) | 5 | <5 |
| TOC | mg/l | | | | 6 | 8 | 3 |
| Kjeldahl-N | mg/l | | | | 0.3 | 0.4 | 0.3 |
| Ammonia-N | mg/l | | | | 0.089 | 0.097 | 0.080 |
| Nitrite-N | mg/l | | | | 0.004 (3/4) | 0.009 | <0.001 |
| Nitrate-N | mg/l | | | | 0.42 | 0.51 | 0.36 |

Table 8. Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/l | | | | 0.018 | 0.029 | 0.010 |
| Cadmium | mg/l | | | | | <0.0001 | |
| Chromium | mg/l | | | | 0.007 | 0.009 | 0.002 |
| Iron | mg/l | | | | 0.40 | 0.51 | 0.29 |
| Lead | mg/l | | | | 0.002 | 0.002 | 0.002 |
| Manganese | mg/l | | | | 0.042 | 0.046 | 0.036 |
| Mercury | mg/l | | | | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 9. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R3

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 64 | 78 | 54 | | | |
| Total Solids | mg/l | 86 | 106 | 69 | | | |
| Total Suspended Solids | mg/l | 4 | 5 | 3 | Station R3 Was Not Sampled | | |
| pH | SU | 7.50* | 7.65 | 6.98 | During the Second Survey. | | |
| Total Alkalinity | mg/l as $CaCO_3$ | 38 | 40 | 36 | | | |
| Chloride | mg/l | 6.0 | 7.5 | 4.5 | | | |
| Sulfate | mg/l | 12 | 25 | 7 | | | |
| Total Hardness | mg/l as $CaCO_3$ | 40 | 41 | 36 | | | |
| Calcium | mg/l | 9.5 | 10.2 | 9.0 | | | |
| Magnesium | mg/l | 4.0 | 4.1 | 3.8 | | | |
| Sodium | mg/l | 2.6 | 2.8 | 2.5 | | | |
| Potassium | mg/l | 1.6 | 1.6 | 1.6 | | | |
| Dissolved Oxygen | mg/l | 9.6 | 9.8 | 9.5 | | | |
| BOD | mg/l | 1 | 2 | 1 | | | |
| COD | mg/l | 8 (2/4) | 10 | <5 | | | |
| TOC | mg/l | 3 | 5 | 1 | | | |
| Kjeldahl-N | mg/l | 0.1 | 0.2 | 0.1 | | | |
| Ammonia-N | mg/l | 0.076 | 0.081 | 0.069 | | | |
| Nitrite-N | mg/l | 0.002 (1/4) | 0.002 | <0.001 | | | |
| Nitrate-N | mg/l | 0.53 | 0.54 | 0.52 | | | |

Table 9. Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/l | 0.013 | 0.017 | 0.010 | | | |
| Cadmium | mg/l | 0.0001 | (3/4) 0.0001 | <0.0001 | | | |
| Chromium | mg/l | 0.008 | 0.017 | 0.002 | | | |
| Iron | mg/l | 0.19 | 0.24 | 0.14 | | | |
| Lead | mg/l | 0.001 | (1/4) 0.001 | <0.001 | | | |
| Manganese | mg/l | 0.026 | 0.033 | 0.020 | | | |
| Mercury | mg/l | | <0.0001 | | | | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 10. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R4

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 64 | 70 | 57 | 65 | 72 | 49 |
| Total Solids | mg/l | 75 | 105 | 51 | 71 | 83 | 55 |
| Total Suspended Solids | mg/l | 2 | 4 | 1 | 8 | 12 | 6 |
| pH | SU | 7.65* | 7.70 | 7.20 | 6.90* | 7.05 | 6.60 |
| Total Alkalinity | mg/l as $CaCO_3$ | 37 | 41 | 31 | 26 | 29 | 24 |
| Chloride | mg/l | 5.8 | 7.6 | 4.5 | 12.0 | 15.5 | 8.8 |
| Sulfate | mg/l | 14 | 30 | 7 | 6 | 9 | 4 |
| Total Hardness | mg/l as $CaCO_3$ | 40 | 43 | 37 | 27 | 31 | 24 |
| Calcium | mg/l | 9.7 | 10.6 | 8.7 | 5.7 | 6.8 | 4.9 |
| Magnesium | mg/l | 3.9 | 4.0 | 3.8 | 3.2 | 3.5 | 2.9 |
| Sodium | mg/l | 2.6 | 3.1 | 2.5 | 3.6 | 3.9 | 3.1 |
| Potassium | mg/l | 1.6 | 1.7 | 1.6 | 2.3 | 2.4 | 2.3 |
| Dissolved Oxygen | mg/l | 9.6 | 9.8 | 9.4 | 9.6 | 10.2 | 9.0 |
| BOD | mg/l | 2 | 3 | 1 | 2 | 2 | 2 |
| COD | mg/l | 6 (4/5) | 9 | <5 | 6 (3/5) | 7 | <5 |
| TOC | mg/l | 5 | 8 | 2 | 2 | 4 | 1 |
| Kjeldahl-N | mg/l | 0.2 | 0.4 | 0.1 | 0.4 | 0.4 | 0.3 |
| Ammonia-N | mg/l | 0.077 | 0.094 | 0.058 | 0.083 | 0.11 | 0.063 |
| Nitrite-N | mg/l | 0.002 (2/5) | 0.003 | <0.001 | 0.005 | 0.011 | 0.001 |
| Nitrate-N | mg/l | 0.50 | 0.53 | 0.47 | 0.64 | 0.77 | 0.47 |

Table 10. Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/1 | 0.013 (1/4) | 0.019 | <0.001 | 0.024 | 0.035 | 0.008 |
| Cadmium | mg/1 | 0.0002 | 0.0002 | 0.0001 | 0.0001 (4/5) | 0.0001 | <0.0001 |
| Chromium | mg/1 | 0.006 (1/5) | 0.011 | <0.001 | 0.002 | 0.007 | 0.001 |
| Iron | mg/1 | 0.21 | 0.27 | 0.13 | 0.44 | 0.61 | 0.34 |
| Lead | mg/1 | 0.001 | 0.002 | 0.001 | 0.002 | 0.003 | 0.002 |
| Manganese | mg/1 | 0.026 | 0.035 | 0.016 | 0.056 | 0.074 | 0.047 |
| Mercury | mg/1 | 0.0003 (4/5) | 0.0010 | <0.0001 | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 11 . RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R5

| Parameter | Units | May 1975 | | | October 1975 | | |
|---|---|---|---|---|---|---|---|
| | | Mean | Max. | Min. | Mean | Max. | Min. |
| Specific Conductance | µmhos/cm | 61 | 82 | 52 | 58 | 69 | 50 |
| Total Solids | mg/l | 88 | 100 | 79 | 76 | 80 | 68 |
| Total Suspended Solids | mg/l | 2 | 4 | 1 | 10 | 14 | 6 |
| pH | SU | 7.58* | 7.60 | 6.92 | 6.82* | 7.10 | 6.65 |
| Total Alkalinity | mg/l as $CaCO_3$ | 39 | 41 | 38 | 26 | 28 | 24 |
| Chloride | mg/l | 5.6 | 6.6 | 4.8 | 13.8 | 15.8 | 9.8 |
| Sulfate | mg/l | 15 | 24 | 9 | 6 | 8 | 4 |
| Total Hardness | mg/l as $CaCO_3$ | 40 | 42 | 39 | 29 | 30 | 28 |
| Calcium | mg/l | 9.7 | 10.3 | 9.4 | 6.3 | 6.4 | 6.0 |
| Magnesium | mg/l | 4.0 | 4.1 | 3.8 | 3.2 | 3.4 | 3.1 |
| Sodium | mg/l | 2.6 | 2.8 | 2.4 | 3.4 | 3.9 | 3.1 |
| Potassium | mg/l | 1.6 | 1.6 | 1.6 | 2.4 | 2.5 | 2.4 |
| Dissolved Oxygen | mg/l | 9.7 | 9.9 | 9.5 | 9.8 | 10.1 | 9.1 |
| BOD | mg/l | 3 | 4 | 2 | 2 | 2 | 2 |
| COD | mg/l | 8 (1/4) | 15 | <5 | 6 (1/4) | 7 | <5 |
| TOC | mg/l | 11 | 22 | 1 | 4 | 7 | 3 |
| Kjeldahl-N | mg/l | 0.2 | 0.3 | 0.2 | 0.3 | 0.4 | 0.3 |
| Ammonia-N | mg/l | 0.081 | 0.089 | 0.073 | 0.083 | 0.095 | 0.068 |
| Nitrite-N | mg/l | 0.003 (1/4) | 0.007 | <0.001 | 0.004 (1/4) | 0.009 | <0.001 |

Table 11 . Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Nitrate-N | mg/1 | 0.46 | 0.50 | 0.41 | 0.48 | 0.54 | 0.43 |
| Total Phosphorus | mg/1 | 0.012 | 0.015 | 0.008 | 0.015 | 0.033 | 0.008 |
| Cadmium | mg/1 | 0.0001 (2/4) | 0.0002 | <0.0001 | | <0.0001 | |
| Chromium | mg/1 | 0.016 | 0.048 | 0.004 | 0.013 | 0.031 | 0.001 |
| Iron | mg/1 | 0.14 | 0.15 | 0.11 | 0.55 | 0.70 | 0.48 |
| Lead | mg/1 | 0.001 | 0.001 | 0.001 | 0.002 | 0.003 | 0.002 |
| Manganese | mg/1 | 0.026 | 0.031 | 0.020 | 0.074 | 0.095 | 0.058 |
| Mercury | mg/1 | | <0.0001 | | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 12. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R6
(DAY)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 59 | 72 | 52 | 54 | 59 | 49 |
| Total Solids | mg/l | 85 | 118 | 67 | 76 | 81 | 74 |
| Total Suspended Solids | mg/l | 2 | 5 | 1 | 7 | 8 | 6 |
| pH | SU | 7.60* | 8.00 | 6.44 | 6.70* | 6.90 | 6.60 |
| Total Alkalinity | mg/l as $CaCO_3$ | 39 | 42 | 37 | 26 | 28 | 25 |
| Chloride | mg/l | 5.1 | 6.6 | 4.3 | 11.5 | 15.0 | 8.0 |
| Sulfate | mg/l | 9 | 13 | 7 | 8 | 11 | 4 |
| Total Hardness | mg/l as $CaCO_3$ | 39 | 41 | 37 | 27 | 29 | 26 |
| Calcium | mg/l | 9.1 | 10.0 | 8.5 | 5.5 | 6.0 | 5.1 |
| Magnesium | mg/l | 3.9 | 4.0 | 3.8 | 3.3 | 3.4 | 3.2 |
| Sodium | mg/l | 2.6 | 2.8 | 2.5 | 3.3 | 3.5 | 3.1 |
| Potassium | mg/l | 1.6 | 1.7 | 1.6 | 2.4 | 2.4 | 2.3 |
| Dissolved Oxygen | mg/l | 9.5 | 9.8 | 9.2 | 9.7 | 10.4 | 9.0 |
| BOD | mg/l | 2 | 4 | 1 | 2 | 2 | 2 |
| COD | mg/l | 19 (2/5) | 42 | <5 | | <5 | |
| TOC | mg/l | 22 | 40 | 1 | 8 | 12 | 4 |
| Kjeldahl-N | mg/l | 0.3 | 0.5 | 0.1 | 0.4 | 0.4 | 0.3 |
| Ammonia-N | mg/l | 0.079 | 0.098 | 0.050 | 0.103 | 0.14 | 0.074 |
| Nitrite-N | mg/l | 0.003 (3/5) | 0.007 | < 0.001 | 0.003 | 0.006 | 0.001 |
| Nitrate-N | mg/l | 0.53 | 0.67 | 0.47 | 0.46 | 0.51 | 0.43 |

Table 12. Continued

| Parameter | Units | May 1975 Mean | | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/l | 0.014 | | 0.017 | 0.012 | 0.011 | 0.012 | 0.010 |
| Cadmium | mg/l | 0.0003 | (2/5) | 0.0011 | <0.0001 | | <0.0001 | |
| Chromium | mg/l | 0.008 | (1/5) | 0.026 | <0.001 | 0.004 | 0.007 | 0.003 |
| Iron | mg/l | 0.16 | | 0.20 | 0.13 | 0.59 | 0.68 | 0.52 |
| Lead | mg/l | 0.001 | (1/5) | 0.001 | <0.001 | 0.002 | 0.003 | 0.002 |
| Manganese | mg/l | 0.026 | | 0.035 | 0.018 | 0.088 | 0.114 | 0.065 |
| Mercury | mg/l | | | <0.0001 | | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 13. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA
NEW RIVER STATION R6
(Night)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Specific Conductance | µmhos/cm | | | | 69 | 69 | 68 |
| Total Solids | mg/l | | | | 65 | 69 | 61 |
| Total Suspended Solids | mg/l | No Samples Were Taken at this Station During the First Survey. | | | 7 | 8 | 6 |
| pH | SU | | | | 7.00* | 7.10 | 6.80 |
| Total Alkalinity | mg/l as $CaCO_3$ | | | | 26 | 26 | 26 |
| Chloride | mg/l | | | | 10.6 | 10.8 | 10.4 |
| Sulfate | mg/l | | | | 5 | 5 | 4 |
| Total Hardness | mg/l as $CaCO_3$ | | | | 28 | 30 | 25 |
| Calcium | mg/l | | | | 5.8 | 6.5 | 5.0 |
| Magnesium | mg/l | | | | 3.2 | 3.3 | 3.1 |
| Sodium | mg/l | | | | 3.3 | 3.5 | 3.1 |
| Potassium | mg/l | | | | 2.4 | 2.4 | 2.3 |
| Dissolved Oxygen | mg/l | | | | 9.6 | 9.9 | 9.2 |
| BOD | mg/l | | | | 2 | 2 | 2 |
| COD | mg/l | | | | 14 | 14 | 14 |
| TOC | mg/l | | | | 6 | 8 | 3 |
| Kjeldahl-N | mg/l | | | | 0.4 | 0.4 | 0.3 |
| Ammonia-N | mg/l | | | | 0.072 | 0.079 | 0.065 |
| Nitrite-N | mg/l | | | | 0.007 | 0.007 | 0.006 |
| Nitrate-N | mg/l | | | | 0.53 | 0.56 | 0.49 |

Table 13 . Continued

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Total Phosphorus | mg/1 | | | | 0.031 | 0.035 | 0.026 |
| Cadmium | mg/1 | | | | | <0.0001 | |
| Chromium | mg/1 | | | | 0.001 | 0.001 | 0.001 |
| Iron | mg/1 | | | | 0.50 | 0.50 | 0.50 |
| Lead | mg/1 | | | | 0.002 | 0.002 | 0.002 |
| Manganese | mg/1 | | | | 0.062 | 0.064 | 0.059 |
| Mercury | mg/1 | | | | | <0.0001 | |

*Median Value

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

The higher concentrations of iron, manganese, and lead found in October probably result from a decrease in pH, making the metals more soluble, or an increase in the suspended solids loads carried by the river. Likewise the higher October Kjeldahl nitrogen and total phosphorus levels are probably associated with the suspended solids. Whatever the cause, this shift in background conditions should be kept in mind when comparing May and October survey results at Stations R-4, R-5, and R-6.

During the second survey, Station R-1 was sampled both day and night, R-4 was sampled on four nights when Outfalls 18, 19 and 20 were running, and once during the day when these lines were in operation. R-5 was sampled during the day when Outfall 22 was running, and R-6 was sampled three times during the day and twice at night. Therefore, for station to station comparisons during the October survey, time of sampling must be taken into consideration. Station R-1 (Night), R-4, and R-6 (Night) represent one comparable series, while R-1 (Day), R-5, and R-6 (Day) form another comparable series. On one occasion during the fall survey, all outfalls were running during the day so all river stations were sampled (see Appendix III - 13).

Three trends show up in the river survey data, involving total organic carbon, nitrogen, and chromium. During the May survey, mean TOC levels jumped from 4 mg/l at Station R-1 to 22 mg/l at Station R-6 (see Figure 9 ). Daytime sampling during the Fall survey showed the same downstream increase in TOC, though the increase was not so dramatic. A probable reason for the smaller increase in TOC in the Fall is that typical flows during the second survey daytime sampling were five to ten times higher than flows in May, producing a higher dilution factor. Nighttime samples did not show this TOC increase. As will be discussed later, these observed increases in TOC at downstream stations do not appear to be a result of discharges from the NG #2 Area.

Though differences are not large, nitrogen levels tend to be highest at Stations R-3 and R-4 (see Figures 10 and 11). Increases in nitrate are

FIGURE 9 Radford Army Ammunition Plant

Total Organic Carbon (Mean Values)

May, 1975 and October, 1975

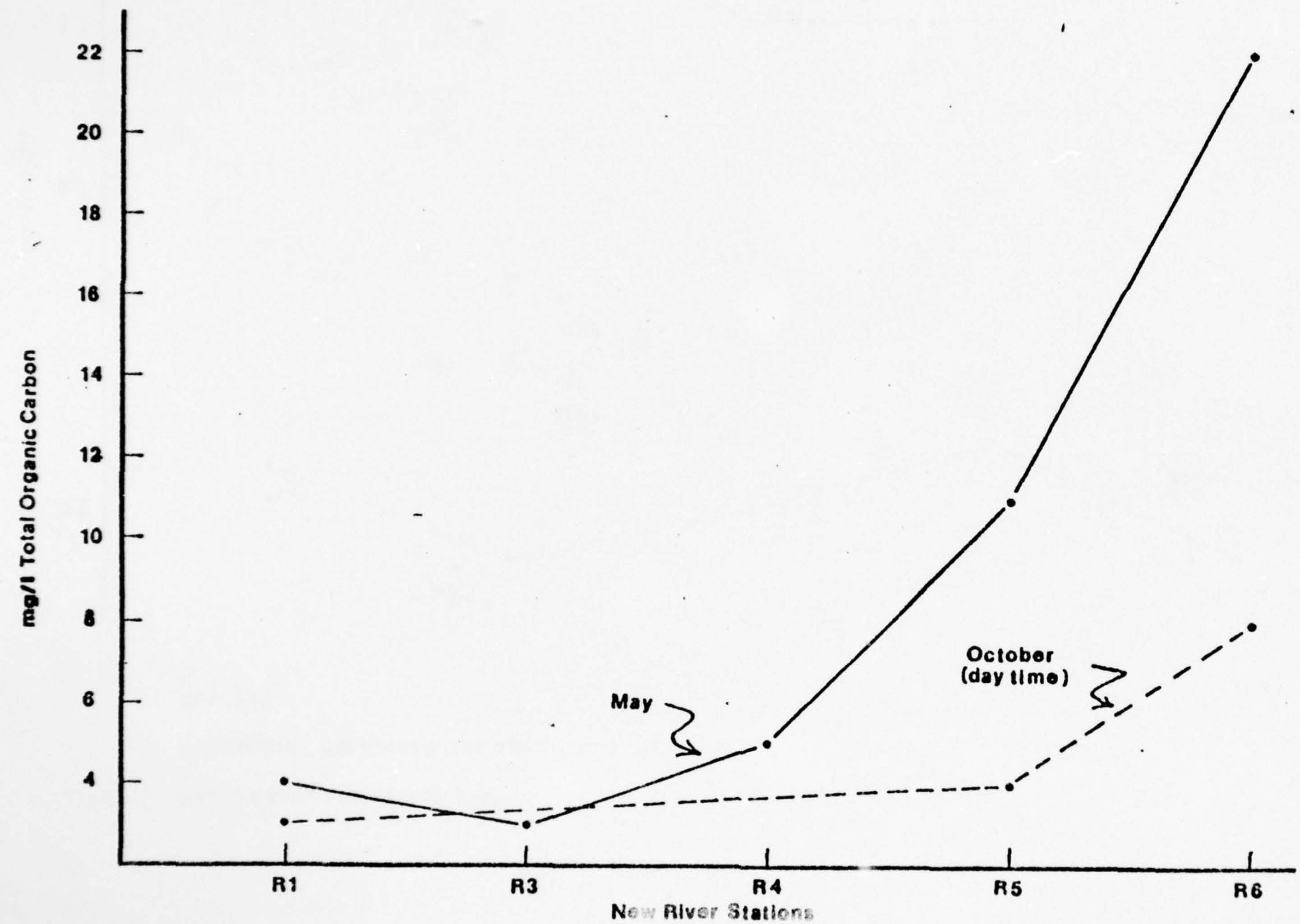


FIGURE 10 Radford Army Ammunition Plant

Nitrate and Total Kjeldahl Nitrogen (Mean Values)

May 1975

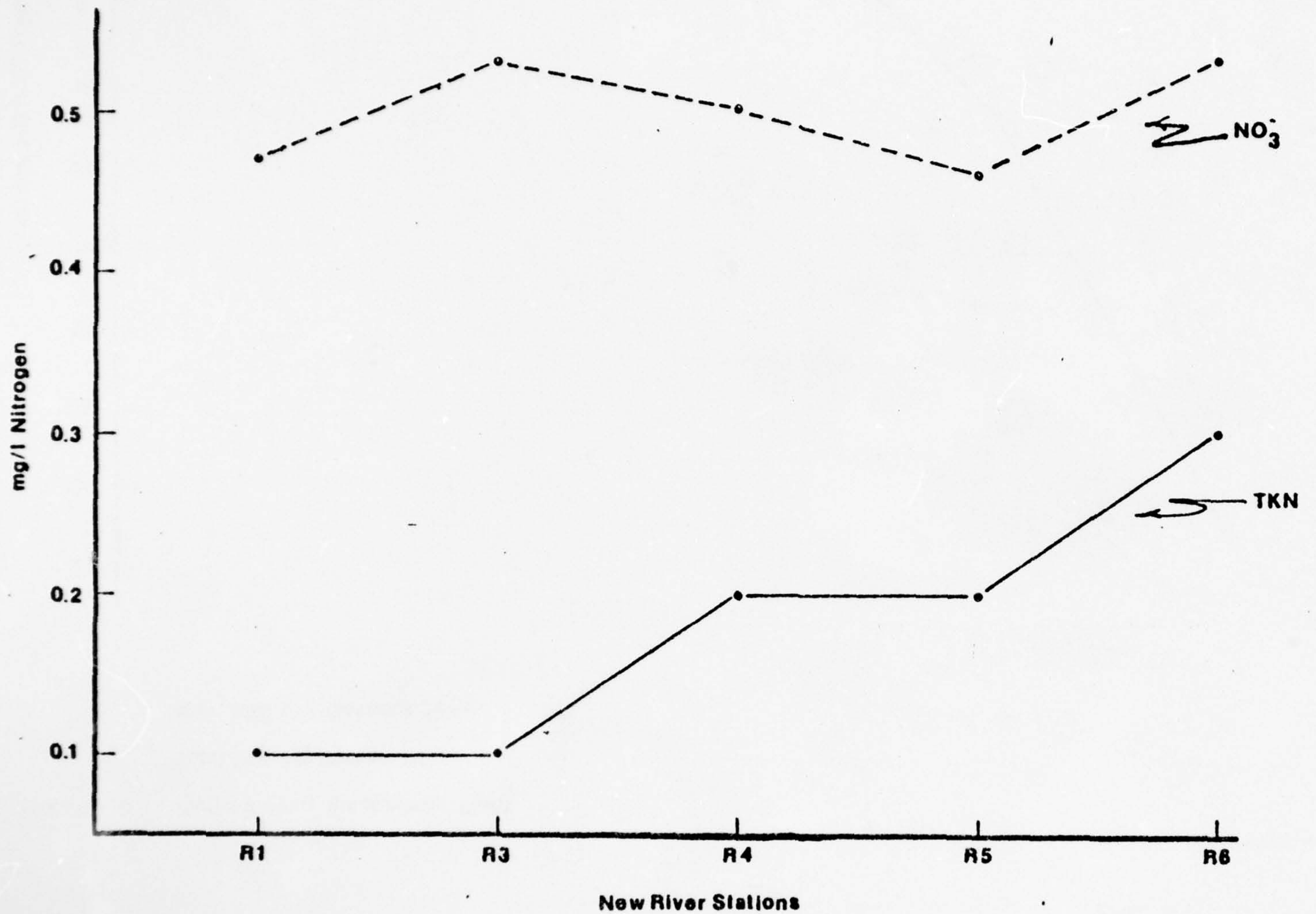
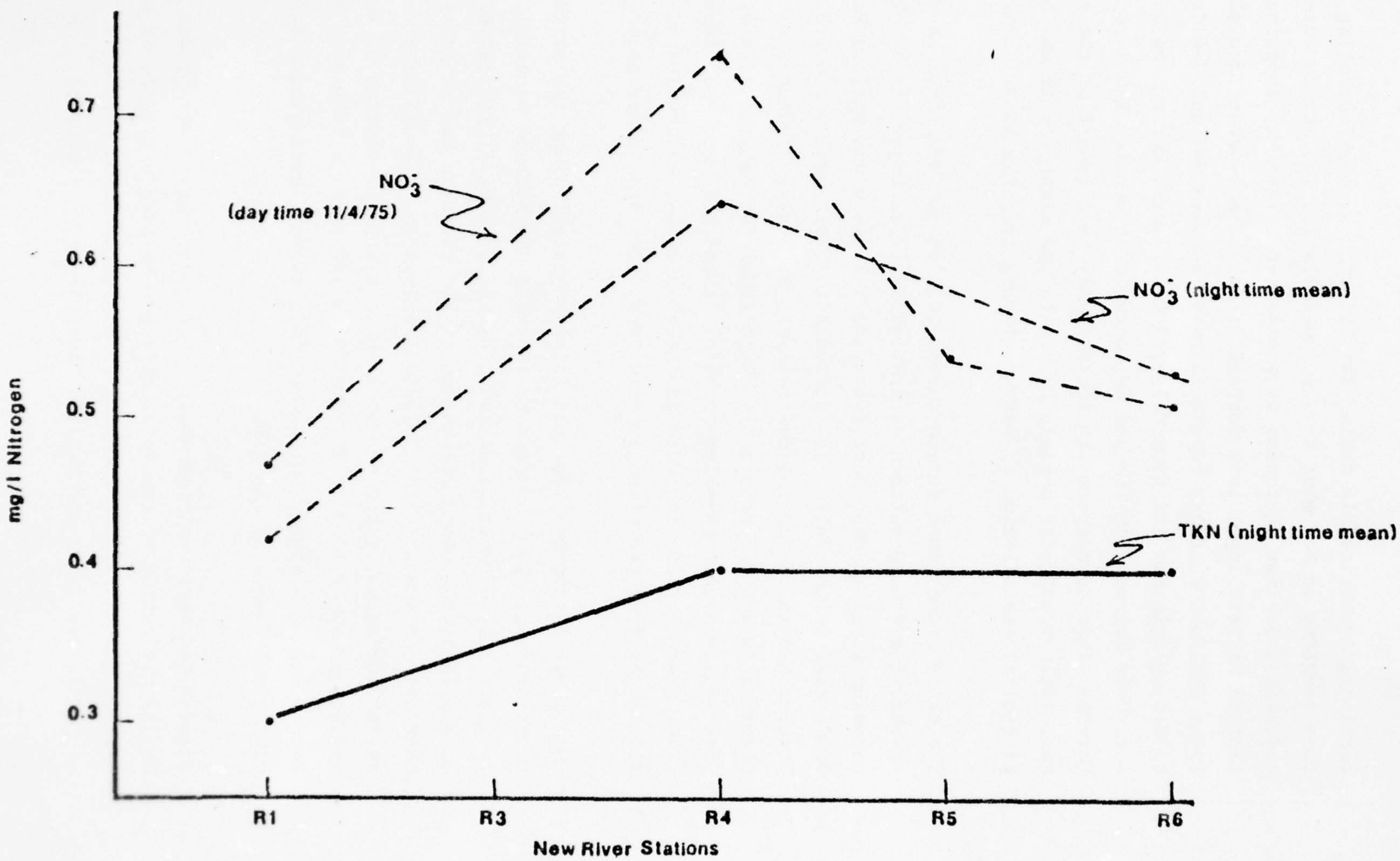


FIGURE 11 Radford Army Ammunition Plant

Nitrate and Total Kjeldahl Nitrogen (Mean Values)

October 1975



AD-A036 777 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD, AND JOLIET ARMY AMMUNIT--ETC(U)
MAR 76 R L WEITZEL, R EISENMAN, J E SCHENK DAMD17-75-C-5046

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particularly noticeable during the Fall Survey night sampling and during daytime sampling on November 4, when Outfalls 18, 19, and 20 were in full operation. Smaller increases were observed during May sampling, due to the limited nitrate input from Outfall 18 during non-production shifts. Total Kjeldahl nitrogen levels increase between R-1 and R-4 from 0.1 mg/l to 0.2 mg/l in May and from 0.3 mg/l to 0.4 mg/l during the October survey. A further increase in TKN and $NO_3$ occured at station R-6 during the May survey. This downstream TKN increase may be a result of the same factors that influenced total organic carbon in the river, or it may be due to biological assimilation of nitrate inputs from the NG #2 Area.

The third trend found during survey work on the New River is an increase in chromium concentrations at Station R-5,(see Figure 12 ). The mean chromium level at the control station R-1 was 0.004 mg/l in May and 0.006 mg/l in the Fall. It increased to 0.016 mg/l and 0.013 mg/l at Station R-5 in the spring and fall, respectively. Though 0.016 mg/l chromium is not an abnormally high level for natural waters, the increase does indicate that chromium is being discharged into the river at the RAAP. However, the increase in chromium cannot be attributed to the sampled discharges from the nitroglycerin production area under study.

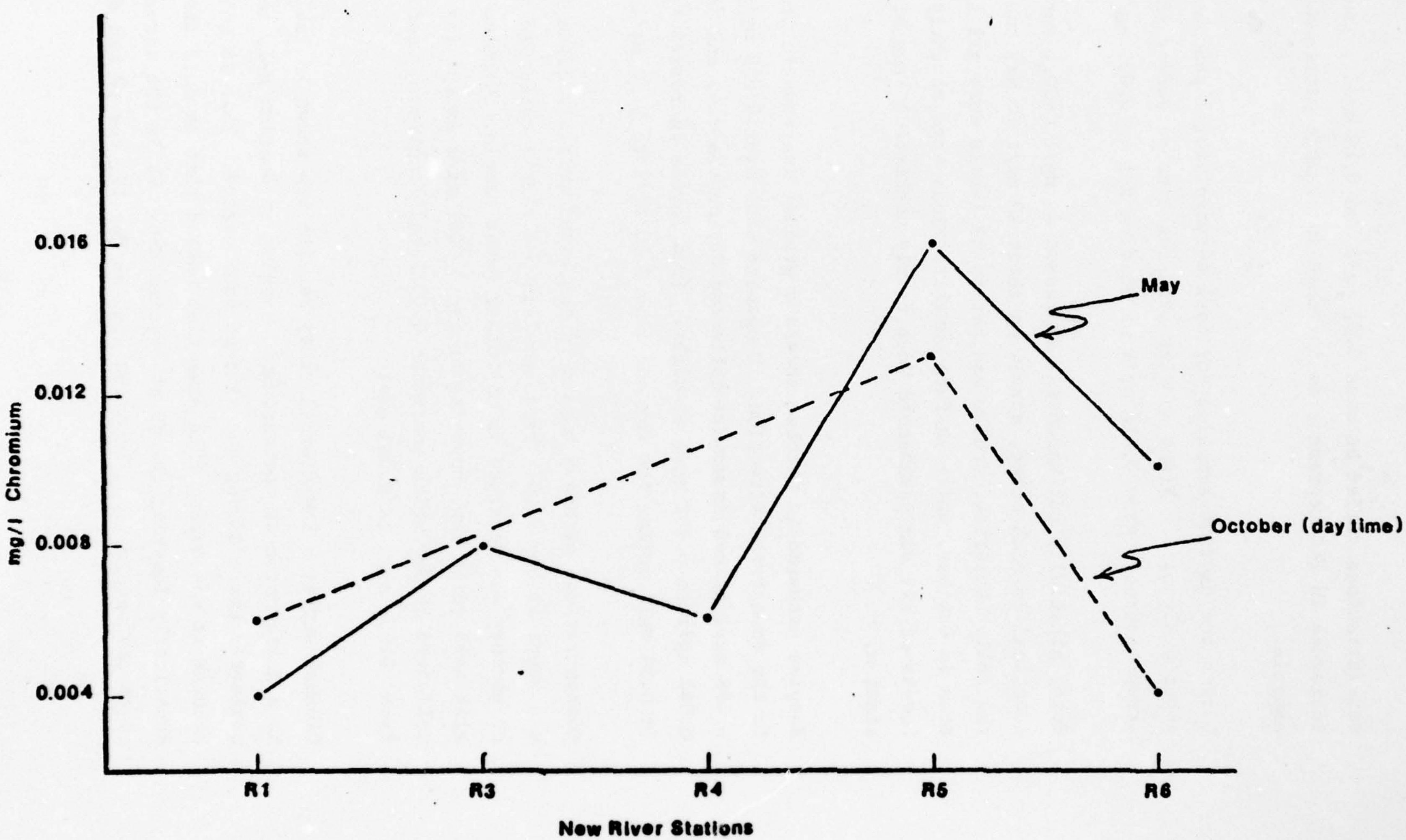
Most other parameters remained fairly constant along the stretch of the river studied. COD did tend to increase downstream, paralleling the increase in TOC. BOD, however, remained constant at 2 mg/l, indicating that the carbon compounds being discharged to the river in the vicinity of the RAAP are not amenable to biological oxidation. Though total solids were higher during the first survey than in the Fall, station to station variation was minimal, staying below 100 mg/l. Suspended solids levels also were higher during the fall survey, averaging 3 mg/l in the spring and 7 mg/l in the fall.

Nitrite nitrogen was present at levels <0.1 mg/l, and so was an insignificant fraction of the total nitrogen balance. Nitrite is readily oxidized to nitrate in aerobic environments and so typically is found at levels twenty to one hundred times lower than nitrate. Ammonia

FIGURE 12 Radford Army Ammunition Plant

Chromium (Mean Values)

May, 1975 and October, 1975



concentrations varied between 0.07 mg/l and 0.10 mg/l. Thus observed increases in TKN represent an increase in organic nitrogen and not ammonia.

During the daytime sampling for both surveys, total phosphorus averaged about 0.014 mg/l. Night samples from the October survey showed a downstream increase from 0.018 mg/l at Station R-1 to 0.031 mg/l at Station R-6.

Total alkalinity and hardness, expressed as mg/l $CaCO_3$, were almost identical to each other, averaging about 40 mg/l in May and 26 mg/l in the Fall. Chloride, sodium and potassium levels were all lower in May than in October, while sulfate concentrations were slightly higher. Levels of all six parameters were fairly consistent from station to station.

Samples gathered in October showed a gradual increase in iron and manganese in the downstream direction. Manganese went from 0.058 mg/l at R-1 to 0.088 mg/l at R-6 in samples collected during the day, and increased from 0.042 mg/l to 0.062 mg/l at night. Iron levels increased from 0.53 mg/l to 0.54 mg/l during the day and from 0.40 mg/l to 0.50 mg/l at night.

Concentrations of heavy metals in the river were all quite low. Mercury was found at the 0.001 mg/l level in one sample collected at R-4, but no mercury was detected in any other water sample. Cadmium concentrations also were quite low, hovering around 0.0001 mg/l except for one sample collected at R-6 which contained 0.0011 mg/l cadmium. Lead levels ranged from 0.001 mg/l to 0.003 mg/l.

Diurnal survey - The diurnal study results are shown in Table 14. Due to a malfunction of the automatic sampler at Station R-1, no samples were collected there during one sixteen hour period. This is quite unfortunate, because it was during this same time period that an acid discharge was drastically lowering the pH at Station R-6. While the normal river pH is approximately 7.80, at 11:00 p.m. on May 19, the pH had dropped to

Table 14 . RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE CHEMICAL DATA-DIURNAL STUDY
NEW RIVER STATION
19-21 MAY 1975

| Date | Time | Station R1 Specific Conductance µmhos/cm | Station R1 pH SU | Station R6 Specific Conductance µmhos/cm | Station R6 pH SU |
|---|---|---|---|---|---|
| 19 May 1975 | 11:00 AM | 80 | 7.90 | - | - |
| | 12:00 | 71 | 7.95 | 55 | 7.70 |
| | 1:00 PM | 70 | 7.95 | 55 | 8.80 |
| | 2:00 | 70 | 7.90 | 71 | 7.95 |
| | 3:00 | 70 | 7.95 | 65 | 7.80 |
| | 4:00 | 70 | 7.95 | 60 | 7.50 |
| | 5:00 | 70 | 7.95 | 62 | 7.85 |
| | 6:00 | 71 | 8.00 | 62 | 7.50 |
| | 7:00 | - | - | 80 | 7.00 |
| | 8:00 | - | - | 95 | 6.50 |
| | 9:00 | - | - | 105 | 6.25 |
| | 10:00 | - | - | 140 | 4.15 |
| | 11:00 | - | - | 355 | 3.15 |
| | 12:00 | - | - | 330 | 3.20 |
| 20 May 1975 | 1:00 AM | - | - | 98 | 6.70 |
| | 2:00 | - | - | 92 | 7.10 |
| | 3:00 | - | - | 95 | 7.05 |
| | 4:00 | - | - | 99 | 6.95 |
| | 5:00 | - | - | 120 | 7.15 |
| | 6:00 | - | - | 90 | 7.15 |
| | 7:00 | - | - | 60 | 7.45 |
| | 8:00 | - | - | 60 | 7.60 |
| | 9:00 | - | - | 260 | 3.41 |
| | 10:00 | - | - | - | - |
| | 11:00 | - | - | - | - |
| | 12:30 PM | - | - | 95 | 7.15 |
| | 1:30 | 56 | 6.96 | 82 | 7.60 |
| | 2:30 | - | - | 81 | 7.80 |
| | 3:30 | 91 | 7.85 | 82 | 7.90 |
| | 4:30 | 58 | 7.75 | 83 | 7.95 |
| | 5:30 | 58 | 7.80 | 52 | 7.80 |
| | 6:30 | 56 | 7.90 | 52 | 7.85 |

Table 14 . Continued

| Date | Time | Station R1 Specific Conductance µmhos/cm | Station R1 pH SU | Station R6 Specific Conductance µmhos/cm | Station R6 pH SU |
|---|---|---|---|---|---|
| 20 May 1975 | 7:30 PM | 56 | 7.95 | 52 | 7.95 |
| | 8:30 | 58 | 7.90 | 52 | 7.90 |
| | 9:30 | 60 | 7.90 | 52 | 7.85 |
| | 10:30 | 60 | 7.85 | 54 | 7.85 |
| | 11:30 | 60 | 7.75 | 52 | 7.90 |
| 21 May 1975 | 12:30 AM | 59 | 7.80 | 52 | 7.85 |
| | 1:30 | 62 | 7.70 | 52 | 7.85 |
| | 2:30 | 60 | 7.65 | 52 | 7.80 |
| | 3:30 | 62 | 7.65 | 52 | 7.85 |
| | 4:30 | 63 | 7.45 | - | 7.65 |
| | 5:30 | 60 | 7.50 | - | 7.70 |
| | 6:30 | 62 | 7.60 | - | 7.75 |
| | 7:30 | 90 | 6.95 | 88 | 7.50 |
| | 8:30 | 90 | 7.25 | 89 | 7.55 |
| | 9:30 | 91 | - | 88 | 7.55 |
| | 10:30 | 91 | 7.55 | 90 | 7.55 |
| | 11:30 | 95 | 7.55 | 90 | 7.55 |
| | 12:30 PM | 98 | 7.55 | 92 | 7.55 |
| | 1:30 | 92 | 7.60 | 94 | 7.65 |
| | 2:30 | 89 | 7.55 | 95 | 7.65 |
| | 3:30 | 89 | 7.65 | 88 | 7.60 |
| | 4:30 | 91 | 7.65 | 87 | 7.65 |
| | 5:30 | - | - | 88 | 7.70 |

Table 15 . RADFORD ARMY AMMUNITION PLANT

DIURNAL STUDY - ACID DISCHARGE

NEW RIVER STATION R6

19 May 1975

| Parameter | Units | TIME 8:00 pm | 9:00pm | 10:00pm | 11:00pm | 12:00am |
|---|---|---|---|---|---|---|
| Chloride | mg/l | 5.0 | 5.0 | 5.2 | 7.0 | 5.0 |
| Nitrate | mg/l | 0.60 | 0.69 | 0.55 | 0.61 | 0.62 |
| Sulfate | mg/l | 33 | 56 | 50 | 93 | 92 |
| pH | SU | 6.50 | 6.25 | 4.15 | 3.15 | 3.20 |

3.15 at Station R-6. The pH recovered to near its normal value, and then dropped again to 3.41 at 9:00 a.m. on May 20th. Diurnal samples with low pH had correspondingly high specific conductance.

It appears that this acid discharge was not related to the NG #2 Area. Routine sampling on May 20th showed that the pH was depressed by 0.4 to 1.2 pH units all along the river. Since Station R-1 is located upstream of any known discharge from the NG #2 Area, the source of the acid must be further upstream.

To establish the nature of the acid discharge, five of the samples showing depressed pH were returned to the laboratory and analyzed for chloride, nitrate, and sulfate. The results are shown in Table 15 . Notice that the drop in pH is accompanied by an increase in sulfate. If one converts the mg/l increase in sulfate to milliquivalents of sulfuric acid, the predicted and observed pH's agree closely, indicating that sulfuric acid is indeed responsible for the drop in pH.

Sediment Phase -

Though collection of sediments samples was described in a previous section of this report, it should be reiterated that in most cases the three cores collected at each station cannot be considered to be replicates. That is, since the substrate was very heterogenous, and much of the substrate was composed of bedrock or cobble and was thus unsuitable for core sampling, cores were taken in such a manner as to encompass a broad range of substrate types. Occasionally it was necessary to take a core from the bank (but below the daily high water mark) because there was no sedimentation occuring in the river at that location.

The 0-10 centimeter sediment data is shown in Tables 16 through 21. Cores from Station R-1 range in substrate type from coarse sands to silts. Unfortunately no clays could be found at R-1 to compare with cores containing clay at one or two of the downstream locations.

Table 16. RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
NEW RIVER STATION R1:
0-10 CM SECTION

| | | 21,23, May 1975 Core Number | | | 4 November 1975 Core Number | |
|---|---|---|---|---|---|---|
| Parameter | Units | R1-1 | R1-2 | R1-3 | R1-1 | R1-2 |
| Total Solids | % | 68.5 | 61.5 | 63.5 | 62.2 | 64.1 |
| Total Volatile Solids | % dry weight | 3.6 | 6.3 | 6.7 | 5.7 | 4.6 |
| COD | mg/g | 11 | 41 | 32 | 27 | 29 |
| Hexane Extractables | mg/kg | 150 | 250 | 220 | 150 | 230 |
| Kjeldahl-N | mg/kg | 380 | 890 | 920 | 1000 | 850 |
| Nitrate + Nitrite-N | mg/kg | 640 | 480 | 540 | 380 | 380 |
| Total Phosphorus | mg/kg | 1150 | 900 | 790 | 1000 | 1020 |
| Cadmium | mg/kg | 1 | 1 | <1 | 2 | 1 |
| Chromium | mg/kg | 10.0 | 15.0 | 15.0 | 23.4 | 12.8 |
| Iron | mg/g | 11.9 | 11.2 | 14.4 | 19.7 | 13.5 |
| Mercury | mg/kg | 0.06 | 0.10 | 0.06 | 0.04 | 0.04 |
| Manganese | mg/kg | 1530 | 930 | 1490 | 1060 | 490 |
| Lead | mg/kg | 193 | 134 | 166 | 220 | 129 |

Table 17 . RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
NEW RIVER STATION R18:
0-10 CM SECTION

| | | 4 November 1975 Core Number | | |
|---|---|---|---|---|
| Parameter | Units | R18-1 | R18-2 | R18-3 |
| Total Solids | % | 54.3 | 36.5 | 49.0 |
| Total Volatile Solids | % dry weight | 6.4 | 11.5 | 8.8 |
| COD | mg/g | 39 | 107 | 67 |
| Hexane Extractables | mg/kg | 2500 | 1050 | 1130 |
| Kjeldahl-N | mg/kg | 1220 | 3020 | 2360 |
| Nitrate + Nitrite-N | mg/kg | 360 | 390 | 360 |
| Total Phosphorus | mg/kg | 1060 | 1300 | 1320 |
| Cadmium | mg/kg | 1 | 2 | 1 |
| Chromium | mg/kg | 26.1 | 26.2 | 26.4 |
| Iron | mg/g | 24.4 | 25.4 | 25.9 |
| Mercury | mg/kg | 0.41 | 0.18 | 0.18 |
| Manganese | mg/kg | 1190 | 900 | 1470 |
| Lead | mg/kg | 298 | 146 | 178 |

Table 18 . RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
NEW RIVER STATIONS R3 &
R19: 0-10 CM SECTION

| | | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | R3-1 | R3-2 | R3-3 | R19-1 | R19-2 | R19-3 |
| Total Solids | % | 61.3 | 50.9 | 62.8 | 65.7 | 74.8 | 60.2 |
| Total Volatile Solids | % dry weight | 7.5 | 12.7 | 6.3 | 3.8 | 2.0 | 5.4 |
| COD | mg/g | 40 | 78 | 39 | 19 | 6 | 39 |
| Hexane Extractables | mg/kg | 420 | 400 | 230 | 230 | 230 | 270 |
| Kjeldahl-N | mg/kg | 1040 | 2030 | 780 | 730 | 660 | 1070 |
| Nitrate + Nitrite-N | mg/kg | 420 | 460 | 460 | 330 | 160 | 410 |
| Total Phosphorus | mg/kg | 990 | 1210 | 1100 | 940 | 830 | 940 |
| Cadmium | mg/kg | 1 | 1 | 2 | 1 | 1 | 1 |
| Chromium | mg/kg | 24.3 | 30.0 | 16.5 | 12.9 | 10.8 | 16.9 |
| Iron | mg/g | 16.9 | 21.6 | 10.3 | 13.3 | 12.2 | 18.8 |
| Mercury | mg/kg | 0.08 | 0.10 | 0.08 | 0.07 | 0.04 | 0.05 |
| Manganese | mg/kg | 720 | 940 | 700 | 670 | 820 | 910 |
| Lead | mg/kg | 98 | 52 | 97 | 98 | 151 | 100 |

Table 19. RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
NEW RIVER STATIONS R4 &
R20: 0-10 CM SECTION

| | | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | R4-1 | R4-1 | R4-3 | R20-1 | R20-2 | R20-3 |
| Total Solids | % | 54.6 | 56.7 | 60.9 | 60.3 | 66.0 | 70.4 |
| Total Volatile Solids | % dry weight | 10.9 | 8.7 | 6.7 | 6.0 | 4.4 | 5.8 |
| COD | mg/g | 54 | 49 | 30 | 44 | 16 | 19 |
| Hexane Extractables | mg/kg | 290 | 340 | 210 | 350 | 320 | 350 |
| Kjeldahl-N | mg/kg | 1390 | 1410 | 1190 | 1440 | 710 | 500 |
| Nitrate + Nitrite-N | mg/kg | 690 | 660 | 380 | 320 | 310 | 370 |
| Total Phosphorus | mg/kg | 1100 | 800 | 940 | 910 | 890 | 1200 |
| Cadmium | mg/kg | 1 | 1 | 1 | 1 | 1 | 1 |
| Chromium | mg/kg | 25.6 | 24.8 | 19.8 | 21.1 | 14.4 | 18.4 |
| Iron | mg/g | 21.2 | 18.9 | 14.5 | 20.5 | 13.9 | 17.9 |
| Mercury | mg/kg | 0.13 | 0.15 | 0.08 | 0.06 | 0.05 | 0.10 |
| Manganese | mg/kg | 2190 | 1510 | 890 | 1070 | 850 | 590 |
| Lead | mg/kg | 114 | 98 | 80 | 84 | 96 | 38 |

Table 20 RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
NEW RIVER STATIONS R5 &
R22: 0-10 CM SECTION

| | | 21,23, May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | R5-1 | R5-2 | R5-3 | R22-1 | R22-2 | R22-3 |
| Total Solids | % | 59.1 | 62.7 | 66.7 | 85.8 | 55.8 | 55.7 |
| Total Volatile Solids | % dry weight | 5.4 | 8.4 | 8.2 | 2.3 | 8.4 | 10.6 |
| COD | mg/g | 17 | 13 | 31 | 3 | 64 | 38 |
| Hexane Extractables | mg/kg | 300 | 140 | 280 | 60 | 310 | 510 |
| Kjeldahl-N | mg/kg | 1000 | 820 | 1260 | 210 | 1750 | 2620 |
| Nitrate + Nitrite-N | mg/kg | 510 | 460 | 620 | 200 | 290 | 510 |
| Total Phosphorus | mg/kg | 1010 | 1620 | 960 | 720 | 1130 | 1340 |
| Cadmium | mg/kg | 1 | 3 | 1 | <1 | 1 | 2 |
| Chromium | mg/kg | 15.0 | 28.7 | 29.4 | 15.4 | 23.0 | 32.8 |
| Iron | mg/g | 9.4 | 35.4 | 15.3 | 10.8 | 23.1 | 28.1 |
| Mercury | mg/kg | 0.29 | 0.27 | 0.12 | 0.03 | 0.05 | 0.13 |
| Manganese | mg/kg | 860 | 2790 | 1780 | 200 | 1680 | 3620 |
| Lead | mg/kg | 106 | 531 | 132 | 26 | 119 | 425 |

Table 21 . RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE CHEMICAL DATA
NEW RIVER STATION R6
1-10 CM SECTION

| | | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | R6-1 | R6-2 | R6-3 | R6-1 | R6-2 | R6-3 |
| Total Solids | % | 60.7 | 61.0 | 66.5 | 52.0 | 56.7 | 57.6 |
| Total Volatile Solids | % dry weight | 10.1 | 7.4 | 7.2 | 5.3 | 7.1 | 5.4 |
| COD | mg/g | 41 | 79 | 30 | 48 | 57 | 57 |
| Hexane Extractables | mg/kg | 520 | 440 | 290 | 520 | 570 | 680 |
| Kjeldahl-N | mg/kg | 1250 | 1450 | 1030 | 1180 | 1640 | 1540 |
| Nitrate + Nitrite-N | mg/kg | 440 | 500 | 410 | 190 | 260 | 320 |
| Total Phosphorus | mg/kg | 950 | 990 | 830 | 920 | 1190 | 990 |
| Cadmium | mg/kg | 2 | 1 | 1 | 1 | 2 | 1 |
| Chromium | mg/kg | 34.9 | 25.0 | 24.9 | 15.3 | 15.4 | 13.7 |
| Iron | mg/g | 11.2 | 15.3 | 10.0 | 16.6 | 15.9 | 13.3 |
| Mercury | mg/kg | 0.12 | 0.13 | 0.19 | 0.09 | 0.10 | 0.08 |
| Manganese | mg/kg | 1380 | 1370 | 1240 | 450 | 880 | 960 |
| Lead | mg/kg | 126 | 124 | 96 | 99 | 105 | 102 |

Chemical oxygen demand (COD) and hexane extractables, and to a lesser degree total volatile solids (TVS), are lower at Station R-1 than at the more downstream stations, paralleling somewhat the aqueous phase TOC results. TVS in the five cores from R-1 ranged from 3.6% to 6.7%. Of the five cores, chemical oxygen demand and hexane extractables was highest in the May Core #2, at 41 mg/g and 250 mg/kg respectively.

Kjeldahl nitrogen was highly variable in cores from Station R-1, ranging from 380 mg/kg to 1000 mg/kg. Downstream concentrations were slightly higher. Total phosphorus and oxidized forms of nitrogen ($NO_3^- + NO_2^-$) levels found at R-1 were fairly typical of the entire stretch of river sampled during this study. Total phosphorus levels here averaged 970 mg/kg, and nitrate plus nitrite ranged from 340 mg/kg to 640 mg/kg in sediments from R-1. As is typical in most aquatic systems the phosphorus-nitrogen ratio in the sediments is greatly enriched in phosphorus relative to the aqueous phase because of adsorption and precipitation mechanisms which sequester phosphorus in the sediment.

Cadmium levels at Station R-1 (1 to 2 mg/kg) were typical of all cores collected in the study area. Lead concentrations are fairly high in the New River sediments. At Station R-1, concentrations ranged from 129 mg/kg to 220 mg/kg. At the downstream station lead usually comprised about 100 mg/kg of sediment. Only one core at Station R-1 contained more than 0.06 mg/kg of mercury, but this core contained 0.45 mg/kg mercury, which was the highest level found in any core during the two surveys. No other metal was particularly high in this core.

Chromium concentrations ranged from 10 mg/kg to 23.4 mg/kg at Station R-1. May sediment cores from the downstream stations contained significantly more chromium than the R-1 cores, as might be expected from the aqueous phase data. However no downstream increase of sediment chromium levels was found in the October survey.

Manganese and iron are typically major components of fluvial sediments. At Station R-1, iron composed 14.1 mg/g of sediment on the average. Manganese levels ranged from 490 mg/kg to 1530 mg/kg.

Cores taken near Outfall I-18 (Table 17 ) are characterized by particularly high concentrations of hexane extractable (1130 - 2500 mg/kg), and by high levels of COD, TKN, mercury, lead, iron, and chromium. Core #1, which contained some clay, was taken right at the mouth of Outfall I-18. The high lead and mercury levels were sorbed from the outfall effluent, as were the hexane extractables. High COD and TKN levels in the other cores, taken a few yards downstream, possibly reflect an increased biomass in the sediment due to enrichment of the water by nitrate.

Though Station R-3 Core #2 had higher than average levels of COD and TKN, in general cores at or below Outfalls I-19 and I-20 (Tables 18 and 19) showed no effects from the discharges.

Lead discharges from Outfall I-22 are reflected in high lead levels in R-5 Core #2 and R-22 Core #3, (see Table 20 ). Both cores are also relatively enriched in all other metals. R-22 Core #3 is also relatively enriched in TKN and oxidized forms of nitrogen.

R-6 sediments are characterized by fairly high levels of COD and hexane extractables. TKN is also fairly high, averaging 1550 mg/kg.

Munitions Compounds

Aqueous Phase -
Industrial outfalls - the highest levels of nitroglycerin were found in Outfall I-22, with a mean of 407 mg/l in May and 222 mg/l in October, (see Tables 22 and 23 ). Outfalls 18, 19, 20, and 21 carried 42 mg/l, 65 mg/l, 83 mg/l, and 101 mg/l respectively in May. In October all four

Table 22. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA

New River Station I18

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 42 | 80 | 2 | 98 | 126 | 75 |

New River Station I19

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate | mg/l | 65 | 30 | 110 | 83.9 | 262 | 1.2 |

New River Station I20

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate | mg/l | 83 | 120 | 39 | 128 | 239 | 47 |

Table 23. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA

New River Station I21

| | | May 1975 | | | October 1975 | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | Mean | Max. | Min. | Mean | Max. | Min. |
| Glycerol trinitrate (nitroglycerin) | mg/1 | 101 | 101 | 101 | 88 | 166 | 16 |

New River Station I22

| | | May 1975 | | | October 1975 | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | Mean | Max. | Min. | Mean | Max. | Min. |
| Glycerol trinitrate | mg/1 | 407 | 637 | 157 | 222 | 306 | 157 |
| O-nitro-diphenyl amine | mg/1 | 5.3 | 14 | 2.6 | 1.8 | 2.7 | 1.0 |

outfalls contained about 100 mg/l nitroglycerin. Because of the large volume of flow from Outfall 18, this outfall carries more than one half of the total amount of nitroglycerin from the NG #2 Area.

Nitro-diphenyl amine (NDPA) was found only in Outfall 22. Concentrations ranged form 2.6 mg/l to 14 mg/l. These values should be considered minimum levels, since the recovery of NDPA was not quantitative.

A complete tabulation of industrial stations munitions data can be found in Appendix IV.

River stations - Nitroglycerin was found sporadically during both surveys at all river stations. A summary of the data is presented in Tables 24 through 26 , while a complete set of munitions data is shown in Appendix IV . A scan of the data in the appendices reveals that no more than one half the samples collected at a station had detectable levels of nitroglycerin. Note that due to improvements in analytical technique, the detection limit was lowered from 0.01 mg/l in May to 0.002 mg/l in October.

Usually NG levels were less than 0.05 mg/l, but one sample collected at Station R-6 during the May survey contained 0.29 mg/l. In general, nitroglycerin concentrations were higher in samples collected during the May survey.

Nitroglycerin was found once during the Fall survey and twice during the May survey at a control station, R-1, which is located upstream of any known discharge from the NG #2 Area. Inquiries at the RAAP led to information that the Roll Powder #1 Area, located upstream of R-1 (see Figure 2 ) may well be a source of nitroglycerin in the New River.

No NDPA was quantified in any river samples, though high pressure liquid chromatograms occasionally indicated its presence, (see Figure 5 ).

Table 24. RADFORD ARMY AMMUNITION PLANT
AQUEOUS PHASE MUNITIONS DATA

New River Station Rl (Day)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 0.02 (2/5) | 0.05 | <0.01 | 0.004 | 0.010 | <0.002 |

New River Station Rl (Night)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate | mg/l | Station Rl was not sampled at night during the first survey. | | | | <0.002 | |

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 25 . RADFORD ARMY AMMUNITION PLANT

AQUEOUS PHASE MUNITIONS DATA

New River Station R3

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 0.01 (4/5) | 0.01 | <0.01 | Station R3 was not sampled during the second survey. | | |

New River Station R4

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate | mg/l | 0.01 (4/5) | 0.03 | <0.01 | 0.008 (2/4) | 0.020 | <0.002 |

New River Station R5

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate | mg/l | | <0.01 | | 0.005 | 0.010 | <0.002 |

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Table 26 . RADFORD ARMY AMMUNITION PLANT

AQUEOUS PHASE MUNITIONS DATA

New River Station R6 (Day)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 0.07 | (3/5) 0.29 | <0.01 | 0.002 | (2/3) 0.003 | <0.002 |

New River Station R6 (Night)

| Parameter | Units | May 1975 Mean | May 1975 Max. | May 1975 Min. | October 1975 Mean | October 1975 Max. | October 1975 Min. |
|---|---|---|---|---|---|---|---|
| Glycerol trinintrate | mg/l | Station R6 was not sampled at night during the first survey. | | | | <0.002 | |

NOTE: "less than" value for Max. indicates material not detected at the indicated level of detection in any sample.

NOTE: numbers in parenthesis represents (number of samples having concentration below indicated detection limit/total number of samples analyzed).

Sediment Phase -

Three sediment extracts from the May survey contained low levels of nitroglycerin. Core #1 at R-3 and Core #3 at R-5 had 1.4 mg/kg NG, and Core #1 at R-6 contained 1.5 mg/kg nitroglycerin (see Tables 27 through 29). With a detection limit of 1.0 mg/kg, no sediments collected during the Fall survey gave positive results.

In addition to nitroglycerin analysis, sediment cores collected at and below Outfall I-22 were analyzed for o-nitro-diphenyl amine. Three of the twelve cores tested gave positive results. In May Core #3 at R-5 and Core #3 at R-6 contained 3.3 mg/kg and 0.7 mg/kg NDPA respectively. In the Fall, Core #3 at R-22 had 12.2 mg/kg NDPA.

Table 27 . RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE MUNITIONS DATA
NEW RIVER STATIONS R1: 0-10 CM SECTIONS
R18: 0-10 CM SECTION

| Parameter | Units | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | |
|---|---|---|---|---|---|---|
| | | R1-1 | R1-2 | R1-3 | R1-1 | R1-2 |
| Glycerol trinitrate (nitroglycerin) | mg/l | <1 | <1 | <1 | <1 | <1 |
| o-nitro-diphenyl amine | mg/l | - | No Data | - | - No Data | - |

| Parameter | Units | 4 November 1975 Core Number | | |
|---|---|---|---|---|
| | | R18-1 | R18-2 | R18-3 |
| Glycerol trinitrate (nitroglycerin) | mg/l | <1 | <1 | <1 |
| o-nitro-diphenyl amine | mg/l | - | No Data | - |

Table 28. RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE MUNITIONS DATA
NEW RIVER STATIONS R3 and R19: 0-10 CM SECTION
R4 and R20: 0-10 CM SECTION

| Parameter | Units | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| | | R3-1 | R3-2 | R3-3 | R19-1 | R19-2 | R19-3 |
| Glycerol trinitrate (nitroglycerin) | mg/l | 1.4 | <1 | <1 | <1 | <1 | <1 |
| o-nitro-diphenyl amine | mg/l | - | No Data | - | - | No Data | - |

| Parameter | Units | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| | | R4-1 | R4-2 | R4-3 | R20-1 | R20-2 | R20-3 |
| Glycerol trinitrate (nitroglycerin) | mg/l | <1 | <1 | <1 | <1 | <1 | <1 |
| o-nitro-diphenyl amine | mg/l | - | No Data | - | - | No Data | - |

Table 29 . RADFORD ARMY AMMUNITION PLANT
SEDIMENT PHASE MUNITIONS DATA
NEW RIVER STATION R5 and R22: 0-10 CM SECTION
R6: 0-10 CM SECTION

| | | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | R5-1 | R5-2 | R5-3 | R22-1 | R22-2 | R22-3 |
| Glycerol trinitrate (nitroglycerin) | mg/l | <1 | <1 | 1.4 | <1 | <1 | <1 |
| o-nitro-diphenyl amine | mg/l | <0.5 | <0.5 | 3.3 | <0.5 | <0.5 | 12.2 |

| | | 21,23 May 1975 Core Number | | | 4 November 1975 Core Number | | |
|---|---|---|---|---|---|---|---|
| Parameter | Units | R6-1 | R6-2 | R6-3 | R6-1 | R6-2 | R6-3 |
| Glycerol trinitrate (nitroglycerin) | mg/l | 1.5 | <1 | <1 | <1 | <1 | <1 |
| o-nitro-diphenyl amine | mg/l | <0.5 | <0.5 | 0.7 | <0.5 | <0.5 | <0.5 |

DISCUSSION

It is brought forth in the results section, that in the area of the New River under study, downstream enrichment occurs with respect to total organic carbon (TOC), nitrogen (TKN + $NO_3$-N) and chromium. The comment was made that is was unlikely that all these observed increases could be attributed to discharges from the NG #2 Area. To provide some insight into the question, the actual mass of four major pollutants from the NG #2 Area discharged per unit time at each outfall was calculated. This was done simply by multiplying the concentration (in mg/l) by the flow rate (in liters/minute) to give mg/minute of each pollutant. By looking at the dilution as these discharges enter the river, an estimate can be made about their impact on background river levels. The flow data used was that obtained from RAAP plant personnel, and concentrations used were an average of Spring and Fall surveys. The discharge inputs of total organic carbon, total nitrogen, lead and nitroglycerin are shown in Table 30. No calculations were made for Outfall I-21, since this discharge is very sporadic and often doesn't reach the river.

Table 30. RADFORD ARMY AMMUNITION PLANT
NG #2 AREA DISCHARGE LOADINGS

| Parameter | Units | I-18 | I-19 | I-20 | I-22 | Total |
|---|---|---|---|---|---|---|
| TOC | mg/min | 11,110 | 10,070 | 4,940 | 2,920 | 29,030 |
| Total N | mg/min | 184,300 | 10,400 | 2,200 | 700 | 197,600 |
| Lead | mg/min | 93 | 4 | 0.7 | 386 | 484 |
| Nitroglycerin | mg/min | 17,090 | 6,950 | 1,970 | 3,470 | 29,480 |

Note that Outfall I-18 carries the most TOC, nitrogen, and nitroglycerin, while Outfall I-22 carries the most lead. Outfalls I-18 and I-19 together discharge 73% of the TOC, 99% of the total nitrogen, and 82% of the nitroglycerin discharged from the NG #2 Area. Both these discharges enter the river between river stations R-2 and R-3. Assuming each line operates eight hours per day, a total of 14.2 kilograms of nitroglycerin is discharged daily from the NG #2 Area.

To estimate the impact that those discharges may have on background river concentrations of each of the four pollutants, some assumptions must be made about river flow and mixing, and losses of pollutants through sorption and degradation. The following assumptions are made here:

1. No sorption or degradation occurs, either as the discharges run down the bluff to the river or as they mix with the river.
2. River flow is 600 cfs (1,019,000 liters/minute). A glance at the flow data in Appendix I shows that this is the lowest flow encountered during the two survey periods.
3. At this flow, 50% of the flow is contained in the main channel running along the north bank of the river.
4. Discharges are completely mixed into the main channel soon after entering the river. Therefore, discharges from the NG #2 Area mix with a river flow of 509,500 liters/minute.
5. All discharges are operating simultaneously, so total discharge inputs from Table 30 can be used.

With the preceding assumptions the following would be the expected increase in river concentrations of the four pollutants under consideration, downstream of all five discharges (i.e. R-5 or R-6).

| Parameter | Expected Increase mg/l |
|---|---|
| TOC | 0.06 |
| Total N | 0.39 |
| Lead | 0.001 |
| Nitroglycerin | 0.058 |

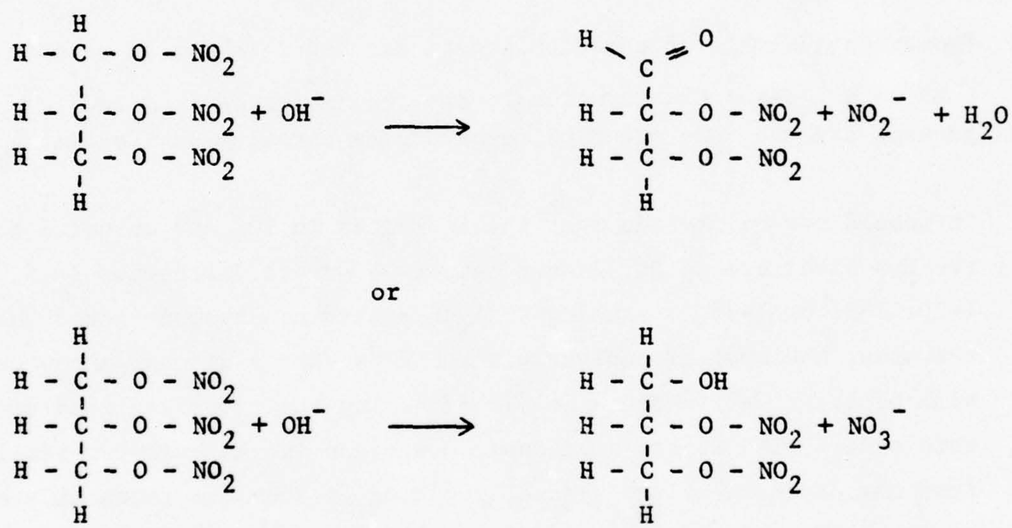
Though no analysis of chromium inputs was made, it can be seen in Tables 2-6 that in all cases the chromium levels are less than lead levels, and in general are the same order of magnitude as chromium levels in the river.

It should now be obvious that the increases in TOC and chromium found in the New River around NG #2 Area cannot be due to discharges I-18, I-19, I-20, I-21 or I-22. Assuming that there are no unknown discharges from the area, the most probable explanation is that a discharge on the other side of the river (south side) is affecting the river stations used in this study. The apparent gradual downstream increase in TOC results from the discharge plume gradually mixing in from the south side of the river to the main channel on the north side where the sampling stations are located. (Should RAAP personnel be interested in identifying this outfall, one clue is that it does not seem to be discharging on Tuesdays. See TOC data for Tuesday, May 20 and Tuesday November 4 in Appendix III.)

Though the above exercise predicts an increase of 0.001 mg/l lead in the downstream stations, lead is quite readily absorbed and transported to the sediments, so the lack of any observed increase is not surprising.

The predicted increase in total nitrogen is fairly close to the observed increases at Station R-4 found during the Fall survey. A rise of 0.1 mg/l TKN and 0.22 mg/l $NO_3$ - N was observed, for an increase in total nitrogen of 0.32 mg/l versus the predicted increase of 0.39 mg/l. Although from the data the prediction would be no increase in TKN and a 0.39 mg/l increase in $NO_3$-N, both algae and bacteria are capable of converting part of the discharged nitrate to organic nitrogen and ammonia.

Predicted nitroglycerin levels in the river are higher than observed levels in the river. On the average, between 0.01 mg/l and 0.02 mg/l were found, while a level of 0.06 is predicted. Under neutral and alkaline conditions, nitroglycerin hydrolyzes to yield either nitrite or nitrate and the corresponding dinitro-carbonyl compounds or alcohols.



This reaction can continue,though at a lower rate, to give singly nitrated species and completely hydrolyzed species. However, the rate of this hydrolysis is fairly low at near neutral pH's. According to rate constants derived by Fraser (in Rosenblatt[14]), it would take 3.4 days for a concentration of 100 mg/l NG to be reduced to 50 mg/l. It is possible however, that in the environment, catalysis of the alkaline hydrolysis of nitroglycerin speeds up the reaction. It is also possible that NG may be involved in reactions with other naturally occuring organic compounds. Also, preliminary studies in our laboratories indicate that microbial degradation of nitroglycerin

can also occur. The fact that no nitroglycerin was found in sediment samples collected during the Fall survey may be related to the fact that aqueous phase NG levels were lower in October than in May.

Nitroglycerin was found at the control station R-1 at approximately the same level that it occurs farther downstream. Though it is conceivable that Outfall I-18 exerts an effect at R-1, it is more likely that the NG is coming from the Roll Powder #1 Area further upstream. If this is the case, other munitions compounds may also be present in the study area.

The high level of nitroglycerin found in one sample collected at R-6 may either represent sample contamination, or a large dump of NG at the RAAP. If the latter is true, the dump may have occured on the other side of the river, and have been carried over to the study area only at R-6, the most downstream sampling station.

In terms of analytical methodology, o-nitro-diphenyl amine (NDPA) proved to pose the biggest problem, mainly because it was not included in the survey protocol until the sampling process had been completed and analysis was well underway. First, it was found that NDPA can be lost during sample extract evaporation. It was also found that NDPA may react with other compounds, including NG, at the elevated temperatures found in the gas chromatrograph. Finally, though high pressure liquid chromatography is a promising method of NDPA analysis, the conditions that had already been developed for NG were not suitable for NDPA because NDPA was not sufficiently resolved from the solvent peak.

In view of the problems encountered, the values for NDPA that are reported should conservatively be considered to be minimum levels. This is particularly true of aqueous phase results, as these samples had already been processed for NG analysis before the NDPA analytical problems were recognized. However, if Outfall I-22 is the only source of NDPA in the study area, river NDPA levels should not exceed 0.001 mg/l.

The only major aqueous phase effect found in this study that can reasonably be attributed to the NG #2 Area is an increase in nitrogen in downstream stations. A small increase in sodium levels at Station 4 during the Fall survey was also noted, but this is of minimal environmental significance. However, in view of; 1) NG being found at the control station; 2) inexplicable increases in TOC and chromium at downstream river stations, and; 3) a sulfuric acid dump which lowered pH's at all river stations, it seems that the dominant influence in the study area is not the NG #2 Area, but some outfall or outfalls located on the other side of the river. This being the case it is difficult, if not impossible, to isolate effects of the discharges in the NG #2 Area from other events in the river.

Localized effects of the NG #2 Area do show up in the sediments. Some effects, like nitroglycerin at Stations R-3, R-5, and R-6, may actually be the result of discharges from areas other than the NG #2 Area. Other effects, however, are attributable to outfalls from the NG #2 Area.

The NDPA found in sediments at Station R-5 and R-6 are certainly from Outfall I-22. Though only one core at Station R-6 showed any trace of NDPA, and then only 0.7 mg/kg, this does indicate that NDPA as well as nitroglycerin is being transported by the river. Future studies may be able to ascertain at what levels NDPA can be found in the river, and what its environmental fate is.

Outfall I-22 also discharges significant amounts of lead, which find their way to the sediments around this outfall. Only cores with clay content showed high levels of lead around at R-22, reflecting the large adsorption capacity of many clays.

Localized effects were also detected in the sediments around I-18 in terms of lead and mercury, COD, TKN, and hexane extractables. Again, high lead and mercury levels were found in the core which contained significant amounts of clay.

If any further studies are to be done they should focus on the localized effects of Outfalls I-18 and I-22. In particular, due to it's potential toxicity, the environmental fate of nitroglycerin and nitro-diphenyl amine should be elucidated. Nitroglycerin has been found to have a significant effect on the survival of fathead minnows at a concentration of 0.09 mg/l [21]. Though NDPA may not be toxic, a reduction product, amino-diphenyl amine has been found to be toxic to animals [22].

## SECTION VII
## BIOLOGY

### DATA ANALYSIS

#### Population Indices

Various mathematical expressions of population diversity were used in comparing the associations of species from the collected samples[23, 24, 25]. Collectively referred to as species diversity indices, these expressions have been used as successful tools for the assessment of the effects of pollution on aquatic biota[23,26,27]. In this survey several indices were applied to the species data in comparisons of replication and as comparisons of species associations between sampling stations. Comparisons were drawn between samples collected from similar substrate types, e.g., glass slide artificial substrates between stations, and between substrate types, e.g., periphyton from rock surfaces compared to samples from artificial substrates. These comparisons were made to determine the maximum potential population available to colonize artificial substrate samplers, which were used to maintain a consistency in sampling techniques. Furthermore, since artificial substrates are somewhat selective, these comparisons would indicate possible effects on species that are in more direct contact with substrates which could sorb the pollutants in question.

Species Diversity -
The Shannon expression (Shannon-Weaver), which is based on information theory, was used to measure species diversity[25,27,28]. This index is not as closely related to the number of individuals per sample as other formulas and is therefore useful in comparing populations represented by varied sample sizes[23]. The Shannon-Weaver diversity expression has been criticized because it is apparently insensitive to the uncommon and rare species although the

significance of rare species to community production is limited, if not questionable[29]. Shannon's diversity is expressed as

$$H' = -\sum_{i=1}^{s} \frac{ni}{N} \log_2 \frac{ni}{N}$$

where:

$H'$ = community diversity

N = total number of organisms

n = number of individuals per taxon

s = total number of species in a unit area

As a point of reference, species diversity values increase as the number of different species in a community increases, while diversity approaches zero when all individuals belong to just a few species .

Species Evenness - In addition to the expression of species diversity, a corresponding evenness expression was also applied to the species data. Evenness (J), which is a measure of the dominance of one or more species, was used as opposed to the similar expression of redundancy (r)[24,25,27,28]. Evenness is expressed as

$$J = \frac{H'}{H\ max} = \frac{H'}{\log S}$$

where:

$$H\ max = \left(\frac{1}{N}\right)\left[\log_2 N! - S \log_2 \left(\frac{N}{S}\right)!\right]$$

Evenness (J) is inversely proportional to redundancy (r) and will tend to parallel species diversity. As pollution increases and there is a corresponding shift to a large number of individuals represented by few taxa, there will be a high redundancy (r) and a low diversity (H') with low evenness (J). Under clean water conditions species diversity and evenness will tend to be high while redundancy is low .

Truncated Normal Curve -

This method of comparison was applied to diatom species data although its usefullness was limited by the number of specimens counted[28, 29, 31]. The truncated normal curve is typically applied to data acquired through "long counts" of 5,000, 8,000, or 10,000 diatoms[28]. Diatom data generated throughout this survey was based on "short counts" of 500 diatoms on each of the sample replicates. These data were then combined to yield effective counts of 1,500 diatoms and 2,5000 diatoms respectively for the enumeration of three and five replicates. Similar to species diversity indices, the truncated normal curve reflects the typical increase of total numbers of individuals with reduced number of total species in response to pollutants[26,28,32].

Coefficient of Similarity

Another means of comparing the biological communities under study was the measurement of the degree of similarity between species associations at different sampling stations. The coefficient of similarity was also used to indicate the degree of likeness between replicate samples. Many researchers have realized that in addition to community structure, i.e., species diversity, similarity of species occurrence is likewise significantly important[26,29,30,33]. One assumes that given identical physicochemical conditions aquatic communities will be similar when sampled from proximal locations within the same system. This concept has been shown to hold true both with distance between stations and with time at the same station within a river system[26,30], unless influenced by waste discharges or other sources of pollution. The coefficient of similarity developed by Pinkham and Pearson[34,35] was applied to the diatom and benthic macroinvertebrate species data of this survey. Different from other coefficients which are based on presence and absence of species, the Pinkham and Pearson coefficient utilizes quantitative data of species occurrence, thereby producing a more reliable comparison of data[34].

For the comparison of replicate and station similarity of periphyton species data collected from artificial substrates, formula "$B_2$" of the Pinkham and Pearson Coefficient of Association was utilized. Mutual absence of species, i.e., 0/0 matches, were ignored[35,36]. This formula is used when organisms of a sample(s) represent a single trophic level. In this case, only diatom species associations were compared. The relative abundance or frequencey of occurrence is an important factor when this formula is used. In comparing populations of the same trophic level the dominance of a single species or the co-dominance of two or three species is important, especially if this dominance is altered between samples or stations.

When periphyton species associations, i.e., diatoms, were compared from samples collected from natural substrates formula "$B_1$" was used with 0/0 matches scored as one[35,36]. This formula is more applicable to samples collected by differing methodologies. In this case, periphyton collected from natural substrates were considered as "different methodology" since different substrate types, i.e., wood surfaces, rock surfaces, and sediment surfaces, were sampled.

## PERIPHYTON

### Analytical Procedures

Species Occurrence -

Species identifications of diatom and non-diatom algae were made on preparations of material collected from natural and artificial substrates. Periphyton on artificial substrates was first scraped from the slides and permitted to settle to the bottom of the sample container. Aliquots were taken from replicate artificial substrate samples and from the natural substrate collections and processed independent of each other. One set of aliquots was held for the identification of non-diatom algae while the second set of aliquots was prepared for permanent diatom mounts.

Diatom dominance - The hydrogen perioxide/potassium dichromate procedure was used for preparing diatom material. Duplicate slide mounts were prepared from each replicate sample using Hyrax™ mounting media[31]. Short counts of 500 diatom frustules were made on each sample replicate from the artificial substrates and from each natural substrate type. Slides were first scanned under low-power magnification (100 X) to visualize even distribution of frustules. If uneven distribution or clumping was observed the slide was discarded. Transects were made across the cover slip and all complete, i.e., non-broken, diatom frustules were identified and enumerated. From these data diatom distribution and percent dominance were determined. Data among replicates and between stations was compared through the use of species diversity, species evenness, and coefficient of similarity. Dominance of a species or species complex is discussed in terms of its relative frequency to other species. This is based on the following classification:

| Percent Occurrence | Relative Frequency |
|---|---|
| 60-100 | abundant |
| 30-60 | very common |
| 5-30 | common |
| 1-5 | occasional (uncommon) |
| 1 | rare |

A species or species group is often referred to as being "dominant" if it has the highest level of occurrence even though its relative frequency is of the common level (5-30 percent). Therefore "dominant" does not necessarily equate with "abundant". Diatoms were identified to the species and variety level using the taxonomic keys of Hansmann, Hohn and Hellerman, Hustedt, Mayer, Patrick and Reimer, Stoermer and Yang, and Weber (Appendix VI).

Non-diatom dominance - A second set of sample aliquots was used for the identification of non-diatom algae. Each sample was concentrated and a one drop subsample was removed and placed on a glass microscope slide.

Coverslips were put into place and sealed with clear fingernail polish. The slides were then dried to form semi-permanent mounts. Transects were observed using 400 X magnification and 200 algal cells were identified and enumerated. High-magnification (1000 X) was used when necessary to identify some individuals to the species level. Ten cells of filamentous forms were counted as one individual. Identifications were made according to the taxonomic keys of Prescott and Smith (Appendix VI). From these counts a species list showing relative abundance was constructed.

Ash-Free Dry Weight -

Formalin preserved samples were returned to the laboratory where the glass slide substrates were scraped with wooden tooth picks to remove the periphyton growth. This material was then filtered onto prerinsed/preweighed Whatman GF/C glass fiber filters (4.25 centimeter diameter; 0.45 micron pore size) and rinsed with distilled water. The filtrate was dried for 24 hours at 100$^{o}$ centrigrade, weighed, ashed for one hour at 550$^{o}$ centigrade, rehydrated with distilled water, dried, and weighed. From this information dry weight (mg/m$^2$) ash-free dry weight (mg/m$^2$), and organic weight produced (mg/m$^2$/day) were calculated [37,38]. Values of replicate samples were plotted and mean and standard deviation were calculated.

Chlorophyll -

Frozen samples were removed from the sample containers and tissue ground with five to eight milliliters 90 percent aqueous acetone and a small amount of magnesium carbonate. Sample volume was then adjusted to ten milliliters with 90 percent aqueous acetone and centrifuged in stoppered centrifuge tubes. An aliquot was taken from the centrifuged samples and absorbance was read on a Gilford spectrophotometer. The trichromatic method was followed as described by Weber[37] and Slack, et al[39]. These data were reported as chlorophyll a (mg/m$^2$), chlorophyll a production (mg/m$^2$/day), and before acidification/after acidification ratio (b/a ratio), which indicates the relative amount of pheophytin in the sample. Mean and standard deviation were calculated on replicate samples and these data were plotted against station location.

Autotrophic Index -

Ash-free dry weight (organic biomass) and chlorophyll a were used in a ratio which indicates the compositional development of the periphyton communities sampled. This ratio, the autotrophic index, is expressed as:

$$\frac{\text{organic biomass } (mg/m^2)}{\text{chlorophyll } \underline{a} \ (mg/m^2)}$$

and has been used to indicate organic pollution and effluent toxicity[37,40]. The numerical value of this index increases with an increase in nonalgal biomass and decreases with an increase in algal biomass. In theory those aquatic systems receiving organic pollution will support a greater biomass of bacteria, fungi, and protozoa rather than algae, thereby raising the numerical value of this ratio ( $> 100$). Under "clean water" conditions with a large biomass of algae the autotrophic index is numerically low, less than 100 being considered as not polluted[37,40].

PERIPHYTON

Results (May-June, 1975)

Species Occurrence -

Diatom dominance on artificial substrates (May-June) - The trend of diatom species diversity on artificial substrates was variable to a small degree. Replication of the five samples collected at each station sometimes varied widely. Table 31 and Figure 13 show the values of species diversity calculated for each sample replicate as well as showing the mean and standard deviation of the replicates for each station. Of the five replicates, usually one was different from the other four replicates at each station. This is indicated by some values occurring outside the limits of the standard deviation at each station. The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of similarity. Using this means of analysis the following was noted:

1. At station R1 the diatom species distribution of the five replicates was similar above the 60 percent level (Figure 14), with four replicates being similar above the 70 percent level. With this in mind the mean species diversity of 1.61 (Table 31) is probably indicative of the diatom population structure at station R1.

2. At station R2 there were four replicate samples which had diatom species similarity above the 85 percent level (Figure 15), while the fifth replicate was similar to the other four at the 50 percent level. The mean diatom species diversity at station R2 was 0.80 (Table 31) but could be considered somewhat lower at 0.63 if the fifth, i.e., most different, replicate was ignored.

Table 31 SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM FIVE REPLICATE ARTIFICIAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE, 1975

| | STATION | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 1.68 | 1.48 | 0.81 | 1.92 | NS* | 1.11 |
| 2 | 1.44 | 0.73 | 0.50 | 1.70 | NS | 1.56 |
| 3 | 1.56 | 0.45 | 0.46 | 1.99 | NS | 1.25 |
| 4 | 1.65 | 0.48 | 0.71 | 1.55 | NS | 1.48 |
| 5 | 1.70 | 0.87 | 0.33 | 1.84 | NS | 1.47 |
| $\bar{x}$ | 1.61 | 0.80 | 0.56 | 1.80 | NS | 1.37 |
| $s^2$ | 0.011 | 0.174 | 0.038 | 0.031 | NS | 0.035 |
| $s$ | 0.107 | 0.417 | 0.195 | 0.176 | NS | 0.187 |

Table 32 SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM FIVE REPLICATE ARTIFICIAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE, 1975

| | STATION | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0.59 | 0.50 | 0.34 | 0.61 | NS | 0.46 |
| 2 | 0.58 | 0.28 | 0.26 | 0.55 | NS | 0.61 |
| 3 | 0.59 | 0.23 | 0.24 | 0.70 | NS | 0.54 |
| 4 | 0.59 | 0.22 | 0.34 | 0.55 | NS | 0.62 |
| 5 | 0.56 | 0.38 | 0.18 | 0.61 | NS | 0.61 |
| $\bar{x}$ | 0.58 | 0.32 | 0.27 | 0.60 | NS | 0.57 |
| $s^2$ | 0.000 | 0.014 | 0.005 | 0.004 | NS | 0.005 |
| $s$ | 0.013 | 0.118 | 0.069 | 0.061 | NS | 0.068 |

*NS means No Sample for that station

FIGURE 13 Shannon-Weaver Species Diversity and Evenness of Periphyton Diatoms Collected from Five Replicate Artificial Substrates. Radford Army Ammunition Plant, New River, Virginia. May—June 1975

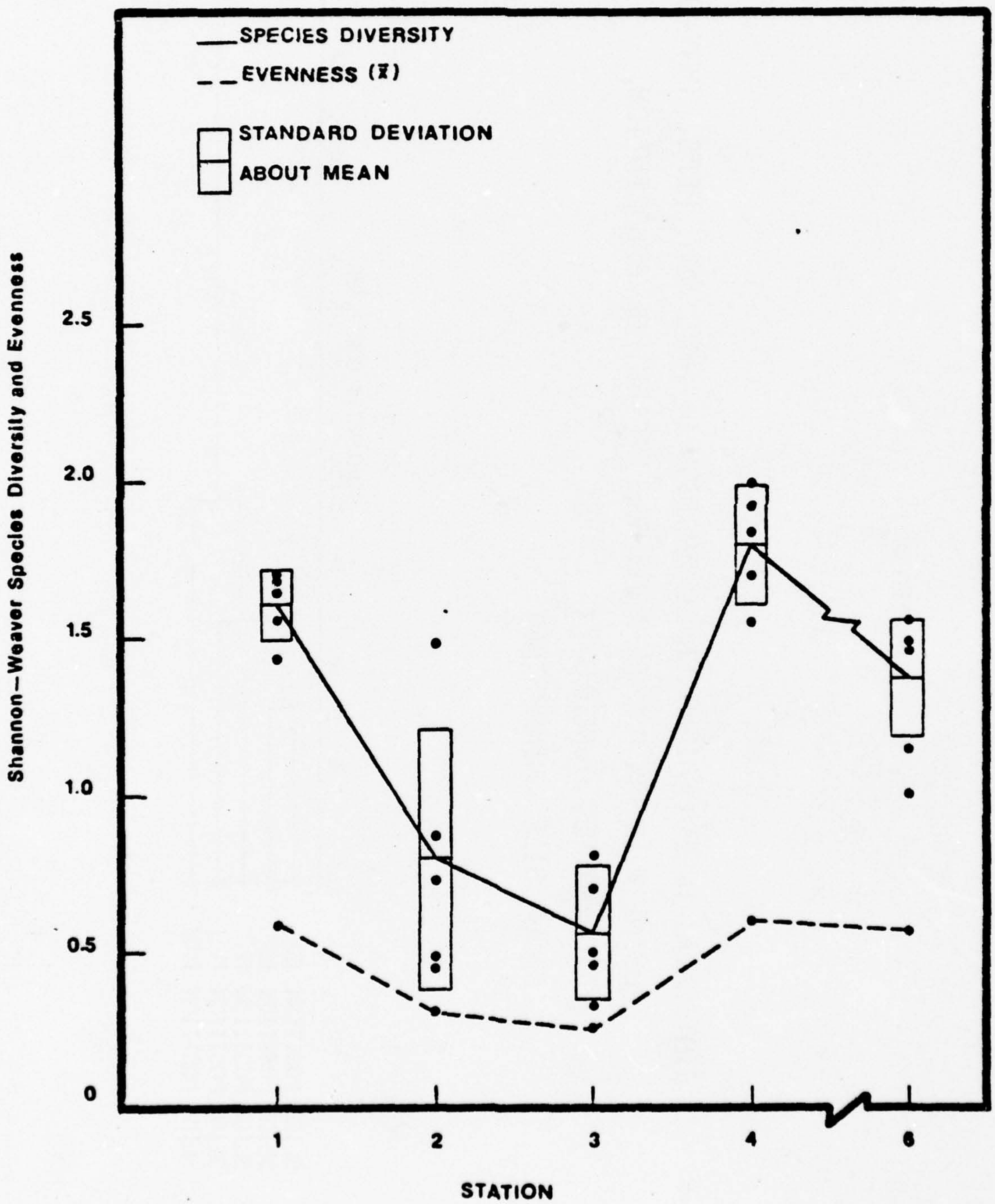


FIGURE 14.

STATION R1-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

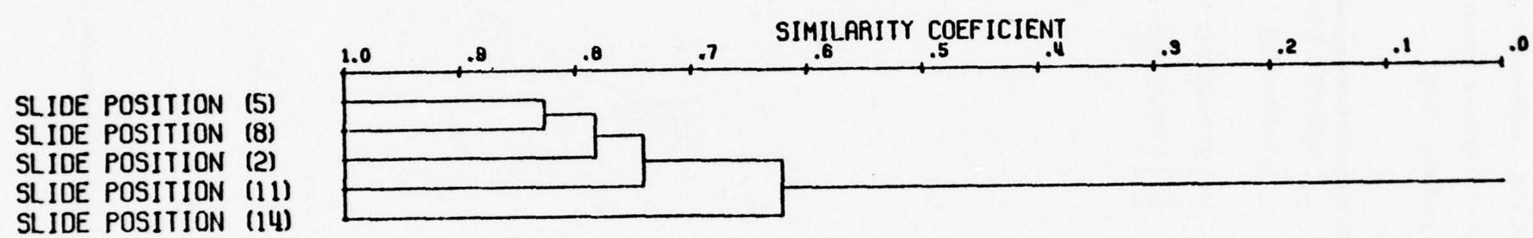
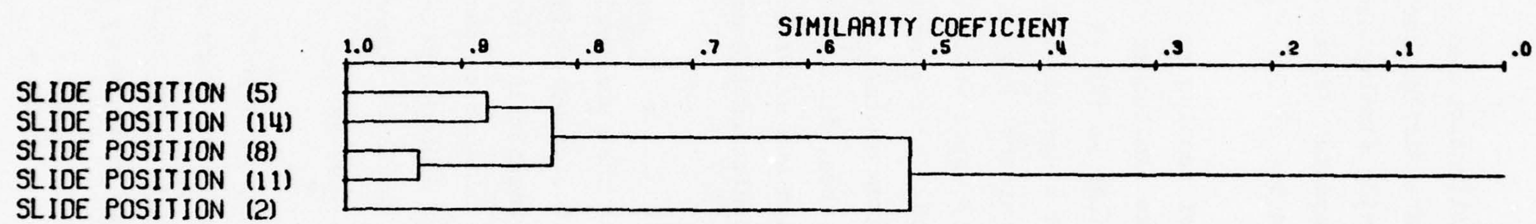


FIGURE 15.

STATION R2-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT



3. Excellent replication was achieved at station R3 where three replicates were similar above the 90 percent level with all replicates being similar above the 85 percent level (Figure 16). Mean diatom species diversity was 0.56 (Table 31) and is most likely indicative of the diatom community diversity at this station.

4. Replication of samples at station 4 was variable. One pair of replicates was similar at the 80 percent level while a second pair was similar at the 75 percent level (Figure 17). The fifth replicate had a species association similar to one pair of replicates at about 39 percent (Figure 17). Mean diatom species diversity was 1.80 (Table 31) which would be quite similar to the mean species diversity (1.82) if the most different replicate was ignored. Since the diatom species associations appeared to differ between sample replicates, it may be suggested that the diatom population at this station was under stress or changing conditions and that the climax population had not been reached at station R4.

5. Replication of diatom species associations at station R6 (Figure 18) was similar to that observed at station R1 (Figure 14). At station R6 three replicates were similar at the 75 percent level with four replicates being similar above the 65 percent level. The fifth replicate was similar to the other four at a level of about 41 percent. Mean diatom species diversity at this station was 1.37 (Table 31) but would be somewhat higher at 1.44 if the most different replicate was ignored.

Through the application of species diversity and coefficient of similarity to the replicate samples at every station, a better description of the diatom community structure was achieved. The degree of sample replication, i.e., species likeness as shown by the coefficient of similarity, indicates

FIGURE 16.

STATION R3-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

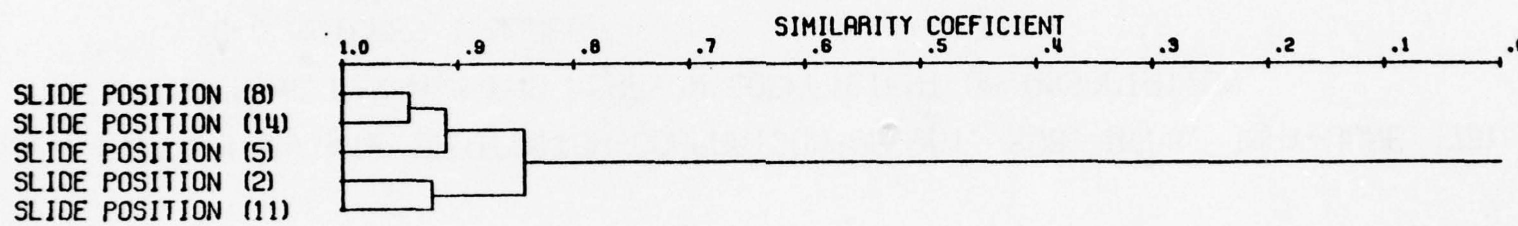


FIGURE 17.

STATION R4-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT

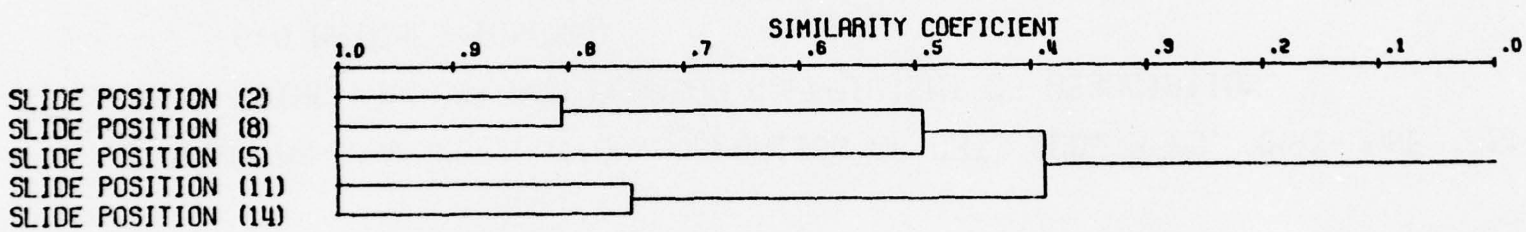
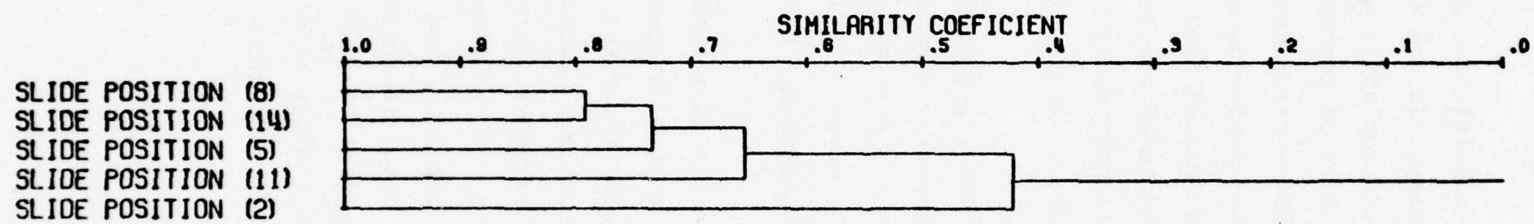


FIGURE 18.

STATION R6-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (MAY-JUNE '75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES IGNORED
GROUP SIZE UNIMPORTANT



whether or not a sufficient sample was taken to adequately describe the existing community. It was shown that most often one of the five replicate samples was quite different from the remaining samples and the presence or absence of its species data had little effect on the estimation of diatom community structure, i.e., species diversity. Thus, the inclusion of all replicate samples on a combined basis at each station provided a broader species complex from which station-to-station comparisons were made. This approach included the occurrence of many rare and uncommon species but did not significantly alter the calculated mean diatom species diversity at the respective stations.

Mean diatom species diversity collected from artificial substrates decreased when moving downstream from station R1 to R3, with station R2 and R3 being similar to each other (Table 31; Figure 13). Species diversity then increased significantly at station R4 with a slight decrease at station R6. Species evenness (Table 32) showed a parallel trend with species diversity.

When diatom species data from replicate samples was combined and then compared between stations using the coefficient of similarity, a trend similar to species diversity was revealed. Station R1 and R6, the upstream reference and furthest downstream stations, respectively, had diatom species associations similar at the 80 percent level (Figure 19). Stations R2 and R3, which had the lowest species diversities, had diatom species associations similar to each other at the 85 percent level, and were similar to the other stations at a level near, or less than, 40 percent (Figure 19). Station R4, which exhibited the highest diatom species diversity (1.80) was similar to stations R1 and R6 at the 62 and 54 percent level respectively (Table 33).

FIGURE 19.
RAAP PERIPHYTON-ART. SUB. COMPARISONS-COMB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

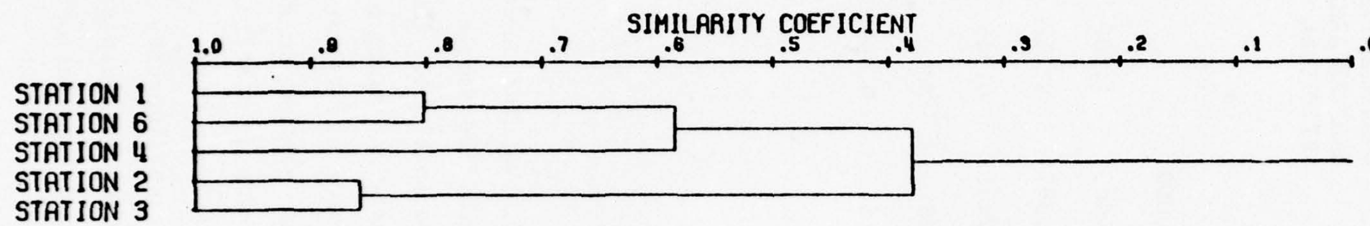


Table 33. COEFFICIENT OF SIMILARITY COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED REPLICATES AT EACH STATION. RADFORD ARMY AMMUNITION PLANT, ARTIFICIAL SUSBSTRATES, MAY-JUNE, 1975.

| Station | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | |
| 2 | 0.463 | 1.000 | | | | |
| 3 | 0.397 | 0.858 | 1.000 | | | |
| 4 | 0.628 | 0.345 | 0.277 | 1.000 | | |
| 5 | *NS | NS | NS | NS | NS | |
| 6 | 0.802 | 0.498 | 0.432 | 0.541 | NS | 1.000 |

*NS - No Samples

Application of the truncated normal curve to the periphyton data[28] revealed that at all five sample stations the height of the mode was in the first or second interval. The length of these curves extended into the twelfth interval. At station R1, R2 and R3 (Figures 20,21, and 22) the height of the mode was low at five or six species. Station R6 (Figure 24) was very similar in shape and trend to station R1, R2 and R3. The height of the mode at station R4 was twice that of the other stations, having 11 species (Figure 23). The same trend had been exposed by the Shannon-Weaver species diversity (Figure 13). Likewise, the coefficient of similarity (Figure 19) showed station R2 and R3, and station R4, to be most different from other stations.

FIGURE 20 Distribution of Diatom Community Collected on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.
May—June, 1975.

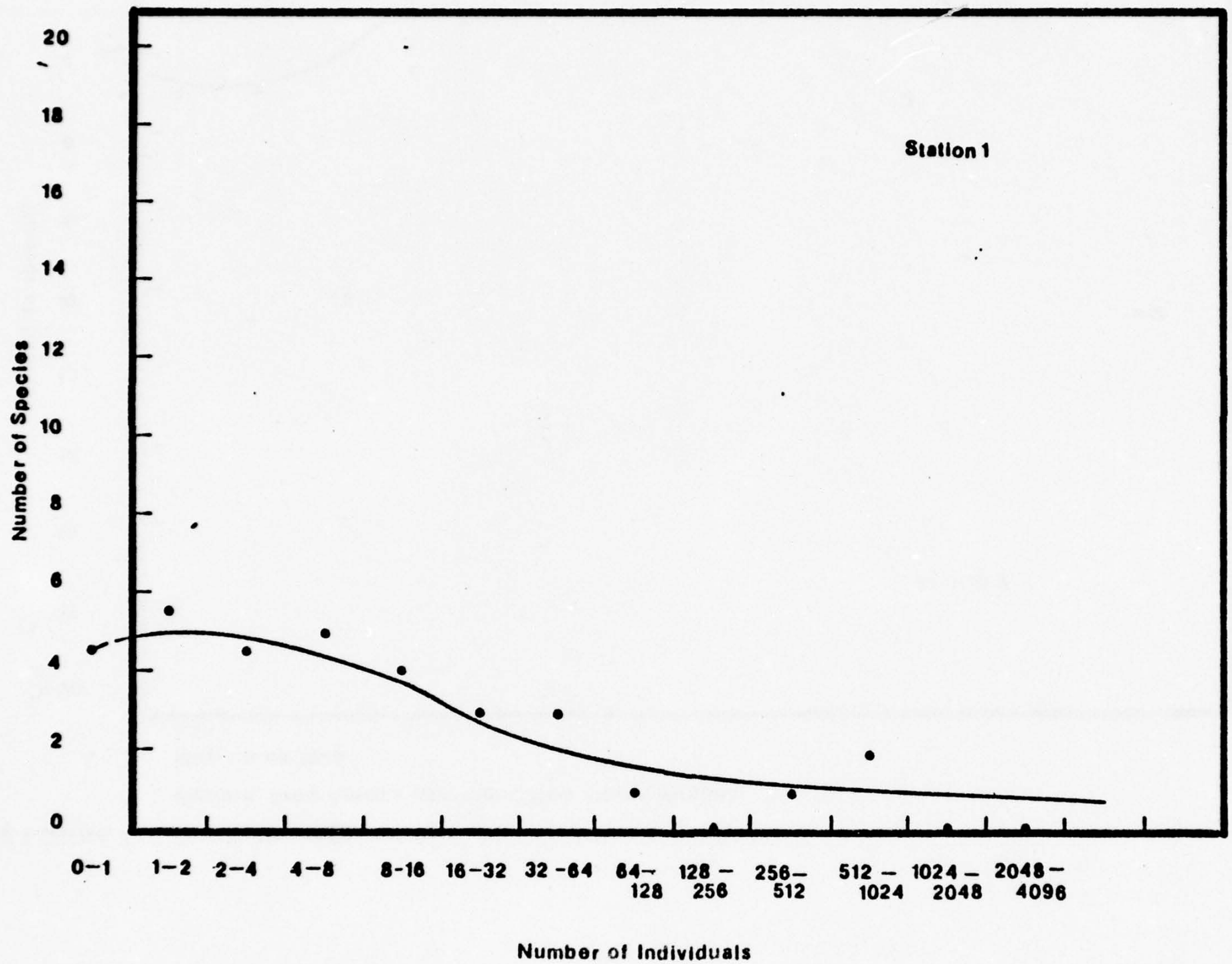


FIGURE 21 Distribution of Diatom Community on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.
May– June 1975.

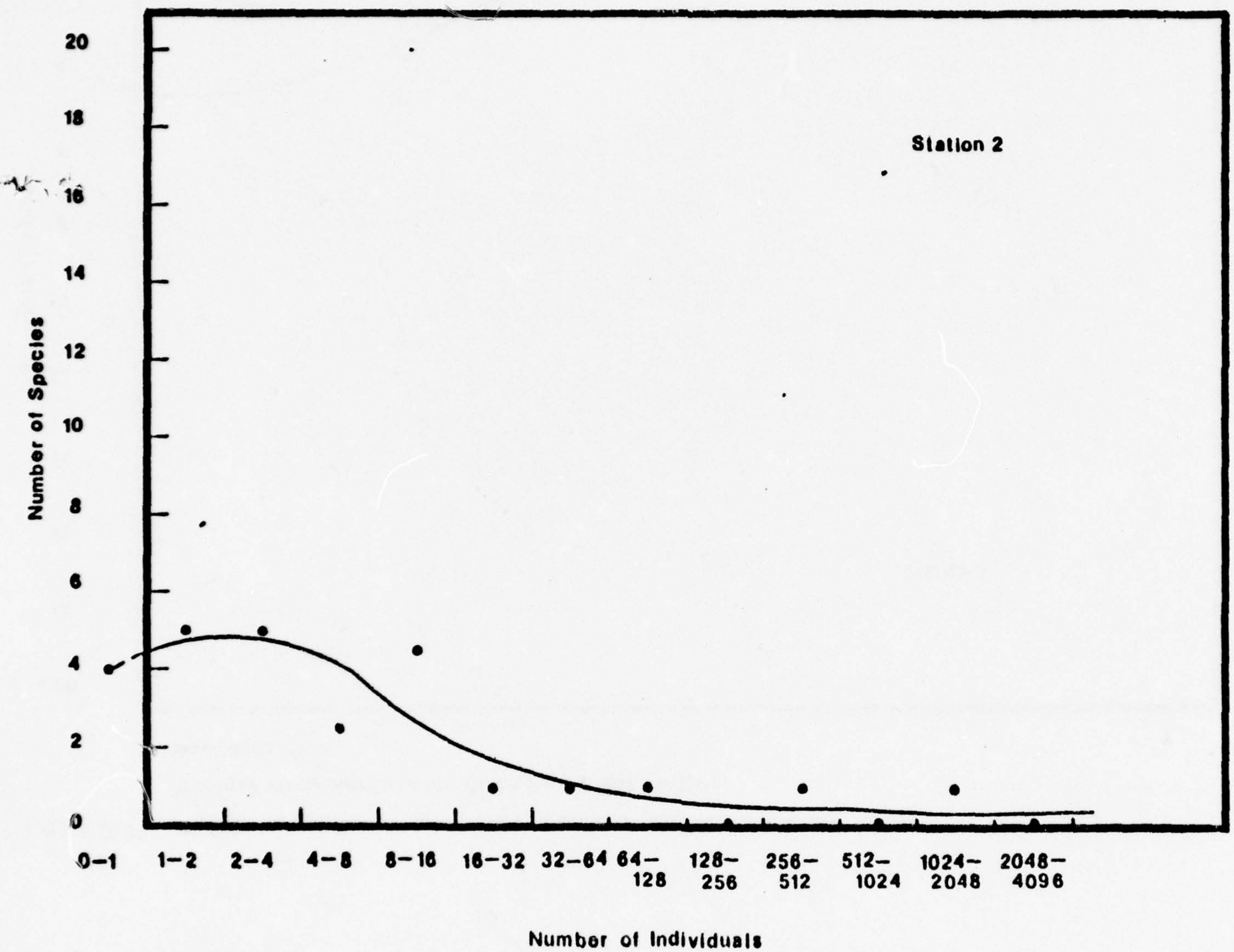


FIGURE 22 Distribution of Diatom Community Collected on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.
May—June 1975

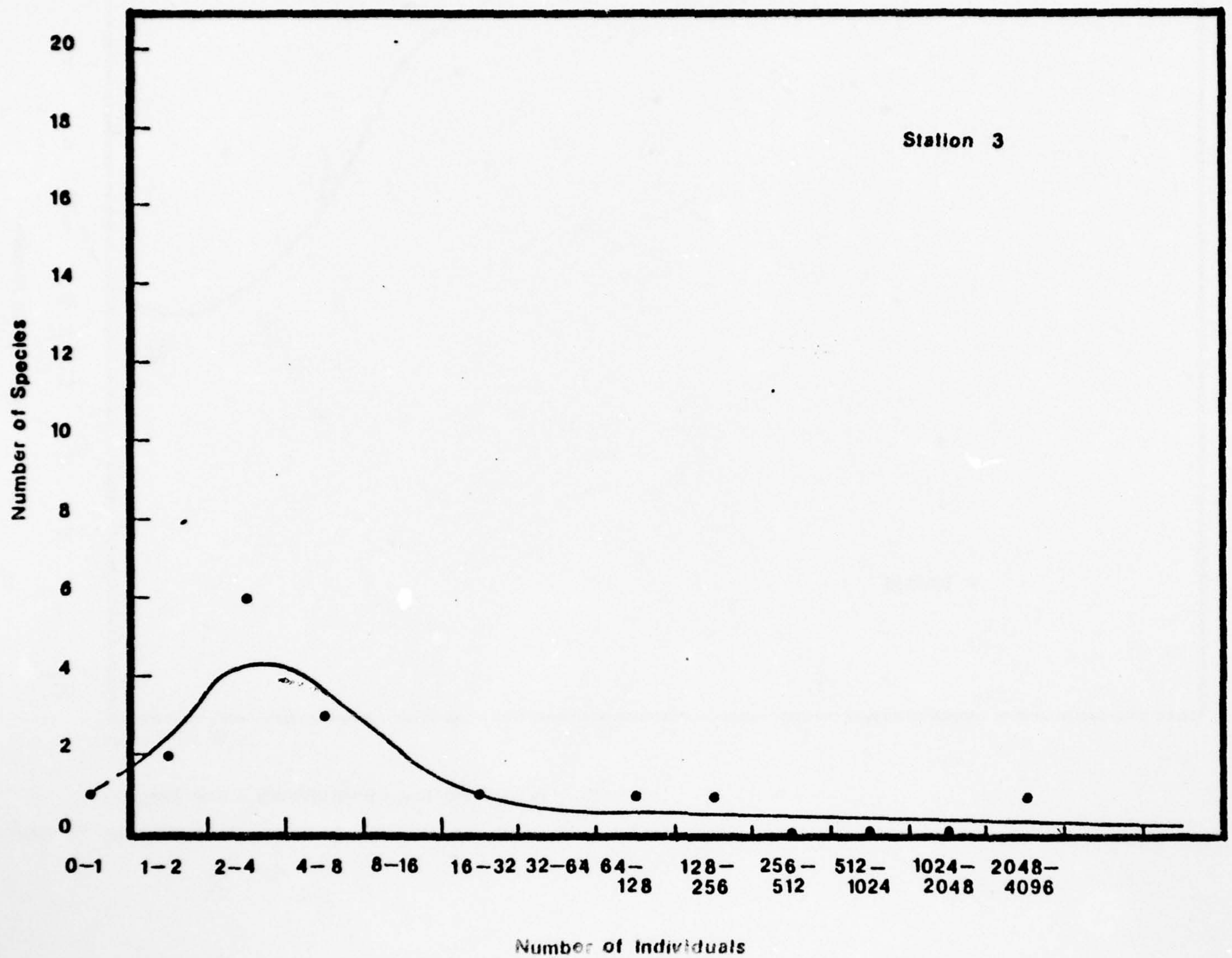


FIGURE 23 Distribution of Diatom Community Collected on Artificial Substrates. Radford Army Ammunition Plant, New River, Virginia.

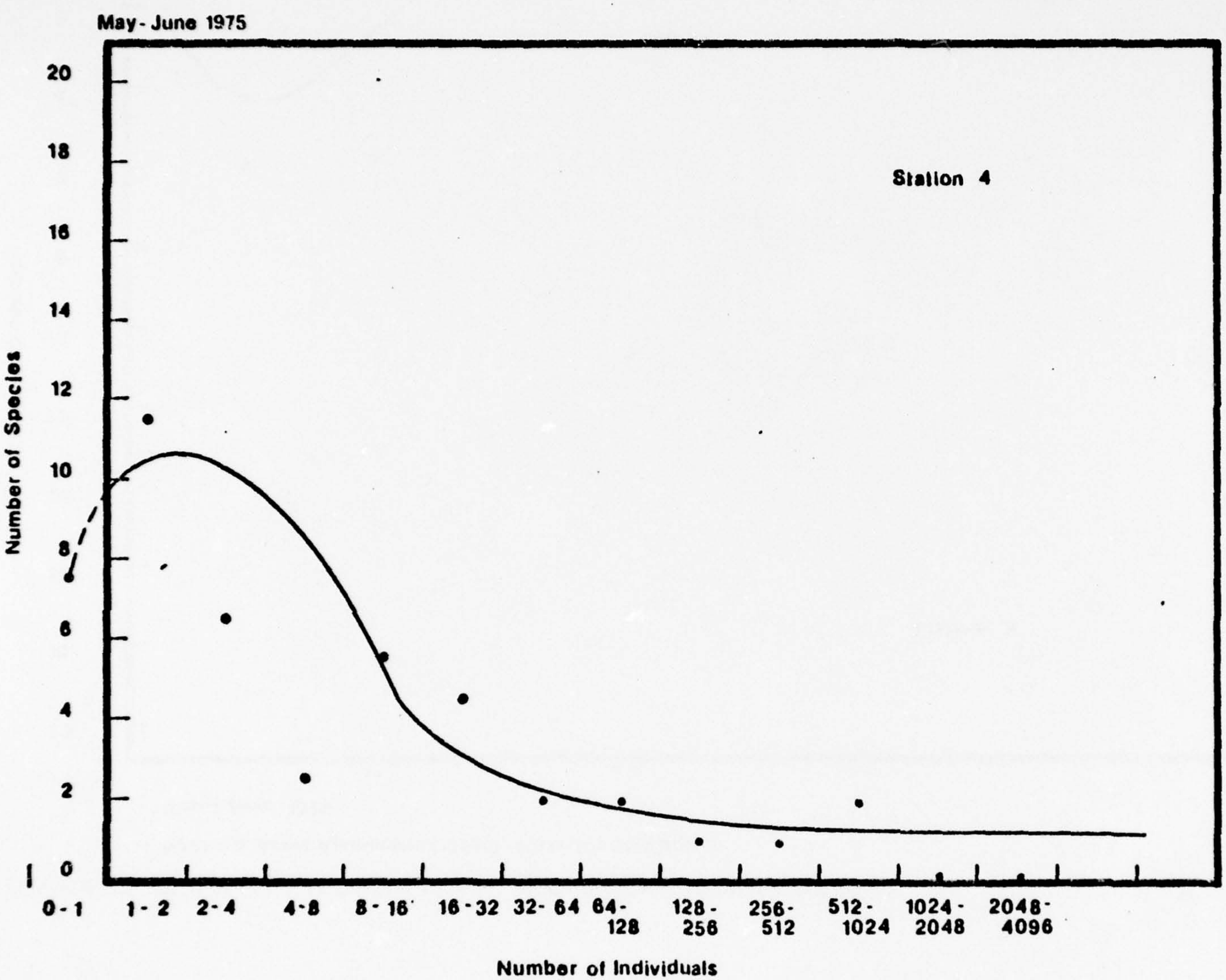
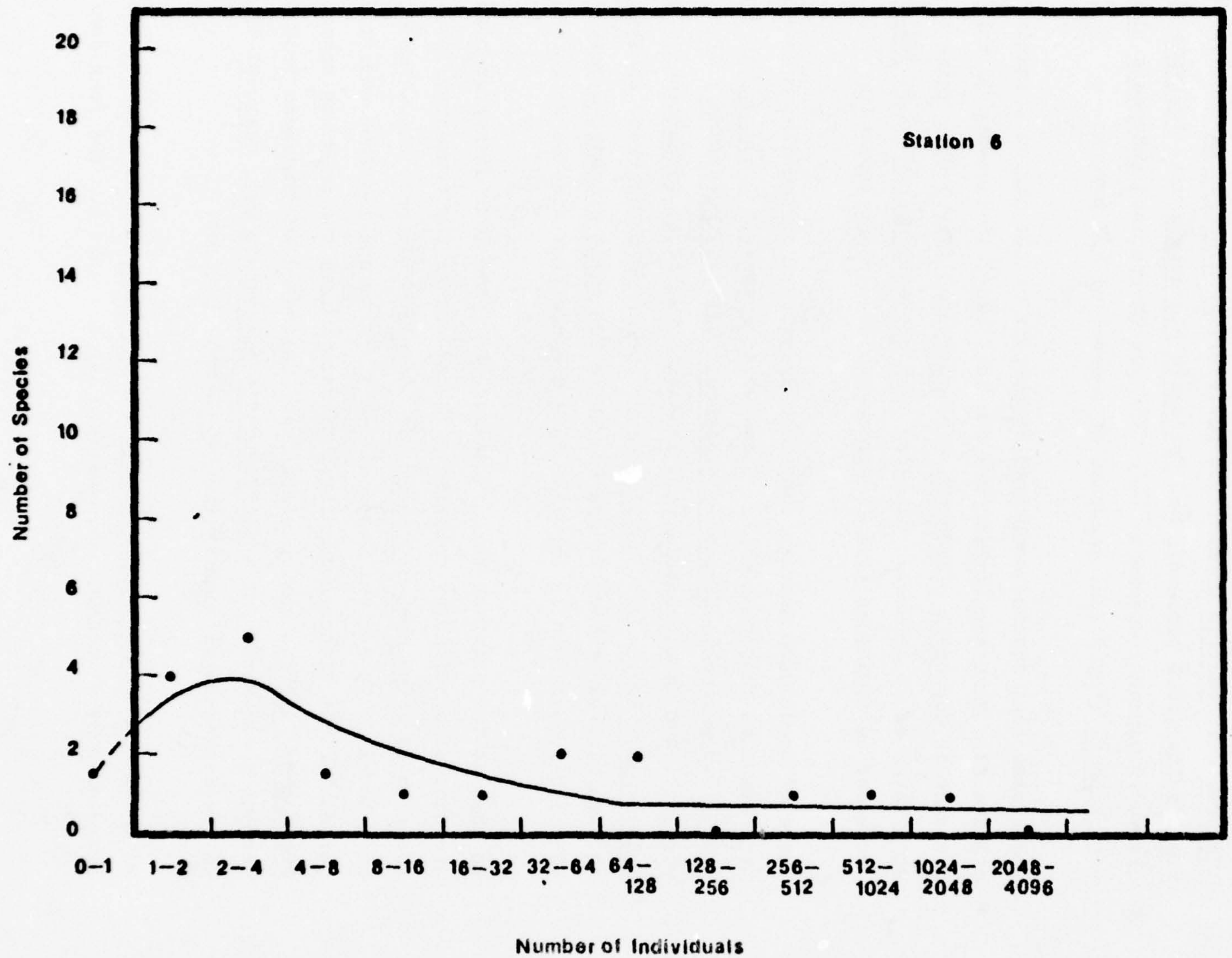


**FIGURE 24** Distribution of Diatom Community Collected on Artificial Substrates. Radford Army Ammunition Plant, New River, Virginia. May–June 1975.



During May-June, 1975, there were four species of diatoms which comprised 86 percent of the diatom association at station R1. These were *Achnanthes linearis* var. *pusilla* Grun. (25.6 percent), *A. minutissima* Kuetz. var. *minutissima* (16.2 percent), and *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. (40.9 percent)(Appendix VII). The fourth species, *Cocconeis placentula* var. *lineata* (Ehr.) V.H. occurred at a level of 4.8 percent.

These same four species comprised 95 percent of the diatom community at station R2. Most significant was the near two-fold increase in the presence of *Cocconeis placentula* var. *euglypta* (Ehr.) Cl., which occurred at a level of 78 percent. Likewise, *Achnanthes linearis* var. *pusilla* Grun. decreased in dominance from 25 percent to 10 percent (Appendix VII).

Three of these same species comprised 97 percent of the diatom community at station R3 (Appendix VII). These were *Achnanthes linearis* var. *pusilla* Grun. (5.9 percent), *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. (86 percent), and *C. placentula* var. *lineata* (Ehr.) V.H. (5 percent). Of these *Achnanthes linearis* var. *pusilla* Grun. continued to decrease in dominance as seen between station R1 and R2, while *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. continued to increase in dominance from station R1 through R3.

As seen at the previous three stations, the same four diatom species were abundant at station R4, comprising 78 percent of the community, plus the addition of *Gomphonema olivaceum* var. *tenellum* (Kuetz.) Cl. which occurred at a level of 14 percent (Appendix VII). Five species thus comprised 93 percent of the diatom community. Different from the previous stations, *Achnanthes linearis* var. *pusilla* Grun. increased in dominance from 5.9 percent to 18.9 percent while *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. decreased significantly from 86 to 28.9 percent.

At station R6 *Gomphonema olivaceum* var. *tenellum* (Kuetz.) Cl., which was abundant only at station R4, was rare (Appendix VII). The four dominant

species as shown previously recurred at station R6. Of these Achnanthes linearis var. pusilla Grun. and Cocconeis placentula var. euglypta (Ehr.) Cl. increased between station R4 and R6. These two taxa comprised 75 percent of the diatom community and were similar to their level of occurrence at the upstream station (R1).

Differences in diatom community structure and similarity which occurred between the five sampling stations were the result of the occurrence, loss, and recurrence of uncommon and rare species, each occurring at a level of between five and one percent or less than one percent, respectively. To summarize Appendix VII, station R1 produced 33 taxa, station R2 - 26 taxa, station R3 had 16 taxa; 45 taxa were found at station R4 and 19 taxa at station R6. The same dominant taxa occurred at all stations but varied in their level of dominance.

Occurrence of non-diatoms on artificial substrates (May-June) - Non-diatom algae comprised a very small percentage of the periphyton community in terms of species occurrence. This occurrence was related only as percent dominance and not as numbers per unit area nor as biomass per unit area. At station R1 the pennate diatoms were dominant at 58 percent. Members of the Cyanophyta (blue-green algae) were of minor importance with the presence of 10 species. Of these, Chroococcus dispersus (Keissl.) Lemm. and Oscillatoria amphibia C.A. Agardh occurred at a level of 10 and 14 percent, respectively (Appendix IV). Chroococcus minor (Kuetz.) Naegeli occurred at a level of six percent while all other species, including two species of Chlorophyta (green algae), occurred at a level of less than two percent.

Similar to the previous station, the dominant algal form at station R2 was the pennate diatoms. Two species of Chlorophyta and seven species of Cyanophyta were present. Of these, Chroococcus dispersus (Keissl.) Lemm. was present at a level of 10 percent, while C. minor (Kuetz.) Naegeli and Oscillatoria amphibia C.A. Agardh were each present at four percent (Appendix VIII). The remaining species occurred at a level of less than two percent.

Station R3 was dominated by pennate diatoms which occurred at a level of 79 percent. Three species of Chlorophyta and nine species of Cyanophyta were found at this station. As previously seen, Chroococcus dispersus (Keissl.) was the dominant non-diatom taxon but occurred at a level of only 7 percent. All other taxa were present at levels less than three percent (Appendix VIII).

There were twelve species of non-diatom algae at station R4, with eight of these being blue-green algae. All non-diatom taxa were present at a level of less than two percent except Oscillatoria amphibia C.A. Agardh which occurred at a level of five percent. Pennate diatoms were again the most dominant algal form at 88 percent (Appendix IV).

Station R6 had 11 non-diatom algal taxa, most being blue-green algae, and all but two species occurring at less than the two percent level. These were Chroococcus dispersus (Keissl.) Lemm. (5 percent) and Oscillatoria amphibia C.A. Agardh (19 percent). Pennate diatoms occurred at a level of 68 percent.

These comparisons showed the pennate diatoms to be dominant at all stations, occurring at levels between 57 and 88 percent. Two non-diatom species, Chroococcus dispersus (Keissl.) Lemm. and Oscillatoria amphibia C.A. Agardh, occurred commonly at all stations. The remaining uncommon species varied in their occurrence between stations.

The application of a simplified species richness formula to these data indicated two areas of variation in periphyton community structure. The formula used was: $S-1/\ln N$ where: S = number of species and N = the number of individuals counted[23]. Species richness varied first between stations R1 and R2, where it decreased from 1.75 to 1.30, and then increased to 1.62 at station R3. Richness again decreased at station R4 where a level of 1.49 was found, which then increased to 1.59 at station R6. These

variations were the result of the loss of uncommon species between these stations and the increase in the number of individuals, especially the pennate diatoms.

Diatom dominance on natural substrates (June) - Species diversity of diatom communities on natural substrates was two to three times greater on natural substrates than found on artificial substrates. A similar trend, although not as great, was observed in terms of species evenness. Diversity on wood substrates was lowest(2.65) at station R1 and highest at station R2, R4,and R5,- 3.37, 3.34, and 3.39, respectively (Table34). Stations R3 and R6 had slightly lower diversities at 3.13 and 3.20, respectively. Little difference was seen in species evenness. Values were high at all stations with the value of 0.70 at station R1 being the lowest (Table 35).

A different trend was observed in comparing diatom species diversity on rock substrates. Highest diversity was found at station R4 (3.33). Next highest were stations R1 and R3, 3.23 and 3.24,respectively (Table 34). Station R6 had the lowest diatom diversity on rock surfaces (2.17) and stations R2 and R5 were higher at 2.71 and 2.89,respectively. Species evenness was high, greater than 0.70, at all stations except R2 and R6, 0.69 and 0.62,respectively (Table35).

A comparison of species diversity based on the means of the wood and rock substrates (Table34) shows the trend to be less variable between stations than that seen previously for artificial substrates (Table31). Mean diatom species diversity from natural substrates was lowest at stations R1 and R6, 2.94 and 2.68,respectively (Figure 25).

The trend showed a slight increase in mean diversity from station R1 to R4, station R4 being highest at 3.33 (Table34). Diatom diversity then decreased from station R4 through station R6. As shown previously, diversity decreased significantly on artificial substrates between stations

Table 34. SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. JUNE 1975

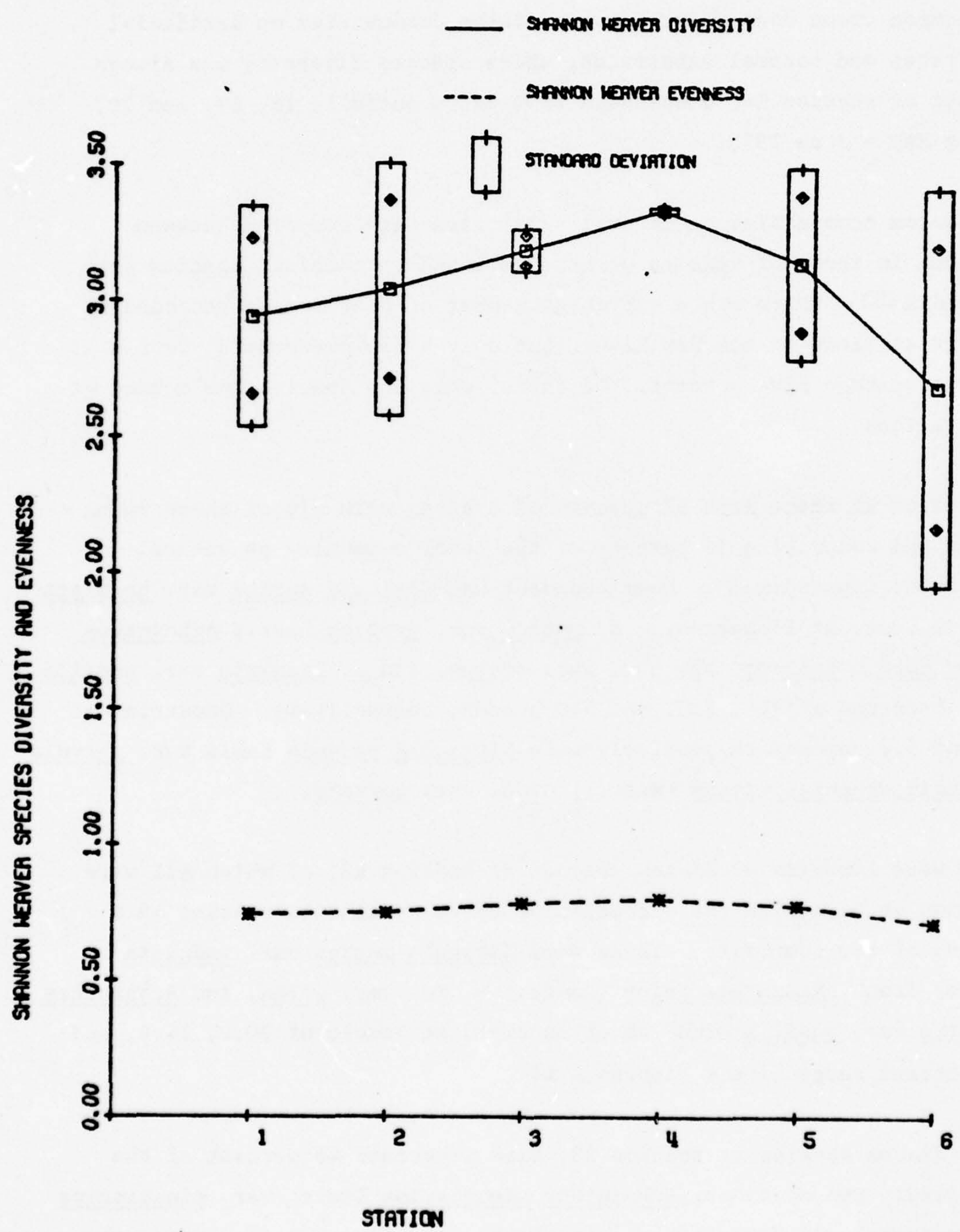
| | Station | | | | | |
|---|---|---|---|---|---|---|
| Samples | 1 | 2 | 3 | 4 | 5 | 6 |
| Wood | 2.65 | 3.37 | 3.13 | 3.34 | 3.39 | 3.20 |
| Rock | 3.23 | 2.71 | 3.24 | 3.33 | 2.89 | 2.17 |
| Sediments | samples incomplete | | | | | |
| $\bar{x}$ | 2.94 | 3.04 | 3.18 | 3.33 | 3.14 | 2.68 |
| $s^2$ | 0.168 | 0.218 | 0.006 | 0 | 0.125 | 0.53 |
| s | 0.41 | 0.48 | 0.08 | 0.01 | 0.35 | 0.73 |
| Combined Diversity* | 3.41 | 3.33 | 3.37 | 3.51 | 3.45 | 3.00 |

Table 35. SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. JUNE 1975

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Samples | 1 | 2 | 3 | 4 | 5 | 6 |
| Wood | 0.70 | 0.81 | 0.78 | 0.81 | 0.82 | 0.81 |
| Rock | 0.79 | 0.69 | 0.79 | 0.80 | 0.73 | 0.62 |
| Sediments | sample incomplete | | | | | |
| $\bar{x}$ | 0.74 | 0.75 | 0.78 | 0.80 | 0.78 | 0.72 |
| $s^2$ | 0.004 | 0.007 | 0 | 0 | 0.004 | 0.018 |
| s | 0.06 | 0.08 | 0.01 | 0.01 | 0.06 | 0.13 |

*Species diversity based on combined species data from wood and rock substrates as opposed to mean diversity of these two substrates.

Figure 25. RAAP PERIPHYTON- DIVERSITY FOR NAT. SUB. (JUNE 75)



R1 through R3, followed by a high diversity at station R4 (Table 31). The common trend does exist between diatom communities on artificial substrates and natural substrates, where species diversity was always highest at station R4, downstream from waste outfalls 18, 19, and 20, during May - June 1975.

The diatom communities on natural substrates were compared between stations in terms of species occurrence based on combined species data (Appendix IX). There was a very high number of diatom taxa recorded at all six stations in the New River, but only a few occurred at levels at or greater than five percent. Of these, only one species was common at all stations.

At station R1 there were 87 species of diatoms with six of these being common and comprising 50 percent of the total community on natural substrates (Appendix IX). Most abundant was Navicula mutica var. undulata (Hilse) Grun. at 13 percent. N. mutica var. tropica Hust., Achnanthes acares Hohn & Hellerm. sp. nov. var. acares, and A. linearis var. pusilla Grun. occurred at 9.1, 8.2, and 7.7 percent, respectively. Occurring at 6.6 and 5.7 percent, respectively were Nitzschia parvula Lewis var. parvula and Rhoicosphenia curvata (Kuetz.) Grun. var. curvata.

There were likewise 87 diatom species at station R2, of which all were uncommon or rare with the exception of three species comprising 40.6 percent of the community. These were Navicula mutica var. undulata (Hilse) Grun., Nitzschia palea (Keutz.) W. Sm. var. palea, and Achnanthes linearis var. pusilla Grun. which occurred at levels of 20.2, 14.6, and 5.8 percent, respectively (Appendix IX).

Of 84 diatom species at station R3, five comprised 46 percent of the community. Two of these, Achnanthes minutissima Kuetz. var. minutissima (7.6 percent) and Navicula gregaria Donk. var. gregaria (7.3 percent)

were uncommon or rare at previous stations. Achnanthes linearis var. pusilla Grun. was most common at a level of 17 percent, a slight increase over the previous stations (Appendix IX).

Four of 92 species were common at station R4 and comprised 40 percent of the diatom community on natural substrates. Most common were Achnanthes linearis var. pusilla Grun. (13 percent) and Nitzschia parvula Lewis var. parvula (11.6 percent). Navicula gregaria Donk. var. gregaria and N. mutica var. undulata (Hilse) Grun. occurred at 7.4 and 8.0 percent, respectively (Appendix IX).

At station R5 four species comprised 35 percent of the diatom community; there was a total of 85 species found. As seen at previous stations Achnanthes linearis var. pusilla Grun. was most common at 18 percent. A. minutissima Kuetz. var. minutissima, Navicula gregaria Donk var. gregaria, and Nitzschia dissipata (Kuetz.) Grun. var. dissipata occurred at 5.0, 6.9, and 5.0 percent, respectively.

Sixty-seven species occurred at station R6 with seven species comprising 63 percent of the diatom community. Most common was Achnanthes linearis var. pusilla Grun. occurring at 25 percent. The remaining six species occurred at a level of less than 10 percent (Appendix IX).

In summary there were 13 diatom species which were common on natural substrates at the six river stations sampled. Only one of these, Achnanthes linearis var. pusilla Grun. was common to all stations. The remaining 12 species occurred at various levels between the six stations, sometimes being absent or only rare and uncommon. Different from diatom species occurrence on artificial substrates, there was never a drastic shift in species dominance of diatom species on natural substrates between stations. Also the abundant or common species comprised a lower percentage of the total diatom community on natural substrates than seen on artificial substrates.

Table 36. COEFFICIENT OF SIMILARITY COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED SPECIES DATA, NATURAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT. MAY- JUNE 1975.

| Station | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.00 | | | | | |
| 2 | 0.483 | 1.00 | | | | |
| 3 | 0.537 | 0.486 | 1.00 | | | |
| 4 | 0.477 | 0.474 | 0.517 | 1.00 | | |
| 5 | 0.528 | 0.489 | 0.571 | 0.522 | 1.00 | |
| 6 | 0.536 | 0.518 | 0.523 | 0.508 | 0.585 | 1.00 |

When the species data gathered from natural substrates was combined at each station and then compared on a station-to-station basis it was found that all stations had similar diatom species associations near or greater than 50 percent (Table 36 and Figure 26). Most similar were the downstream stations R-5 and R-6 (58 percent). Station R-3 paired with these two stations at 56 and 52 percent, respectively (Table 36). In order of lesser similarity to stations R-5, R-6, and R-3 were R-1, R-4, and R-2 (Figure 26).

Differences of diatom communities on natural substrates were insignificant between stations and were the result of the occurrence, loss, and recurrence of uncommon and rare species. No single species showed a significant variation in occurrence and distribution.

Ash-Free Dry Weight (May - June) -

A comparison of ash-free dry weight ($mg/m^2$ and $mg/m^2/day$) showed marked shifts between the five sampling stations during May-June, 1975. As a preliminary note, these variations were not unlike those trends observed for species diversity and evenness. Between stations R-1 and R-2 there was a 46 percent decrease in mean ash-free dry weight as $mg/m^2$ and $mg/m^2/day$ (Tables 37 and 38; Figure 27). This was followed by a 48 percent

Figure 26.

RAAP PERIPHYTON-STATION COMPARISON OF NATURAL SUBSTRATES (JUNE 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

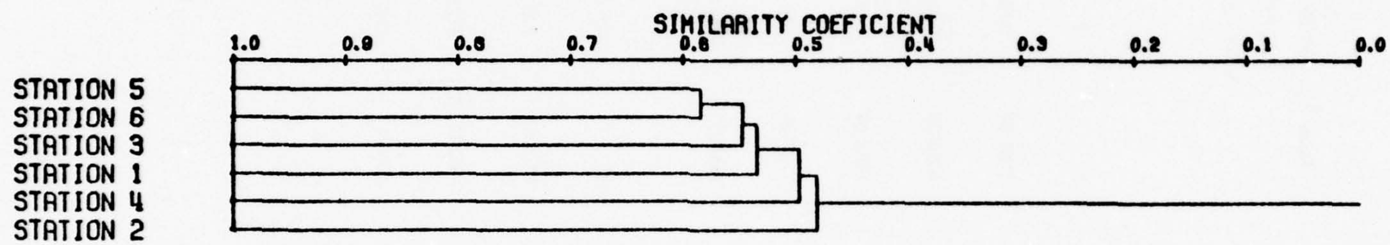


Table 37. PERIPHYTON ASH-FREE DRY WEIGHT ($mg/m^2$).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA.
MAY - JUNE 1975

| Slide Position in Artificial Substrate Sampler | STATION 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Slide 1 | 2101.23 | 860.74 | 481.00 | 1822.75 | NS* | 2658.18 |
| Slide 4 | 1088.59 | 683.53 | 177.21 | 1443.01 | NS | 1620.22 |
| Slide 7 | 1848.07 | 1037.96 | 582.27 | 1974.65 | NS | 1974.65 |
| Slide 10 | 1746.80 | 936.69 | 810.11 | 4126.51 | NS | 1670.86 |
| Slide 13 | 1848.07 | 1113.90 | 379.74 | 2354.39 | NS | 1772.12 |
| Number of Days | 46 | 46 | 46 | 46 | | 45 |
| $\bar{x}$ | 1726.55 | 926.56 | 486.07 | 2344.26 | NS | 1939.21 |
| $s^2$ | 144330.58 | 27751.18 | 55245.66 | 1099338.37 | NS | 179964.82 |
| $s$ | 379.91 | 166.59 | 235.04 | 1048.49 | NS | 424.22 |

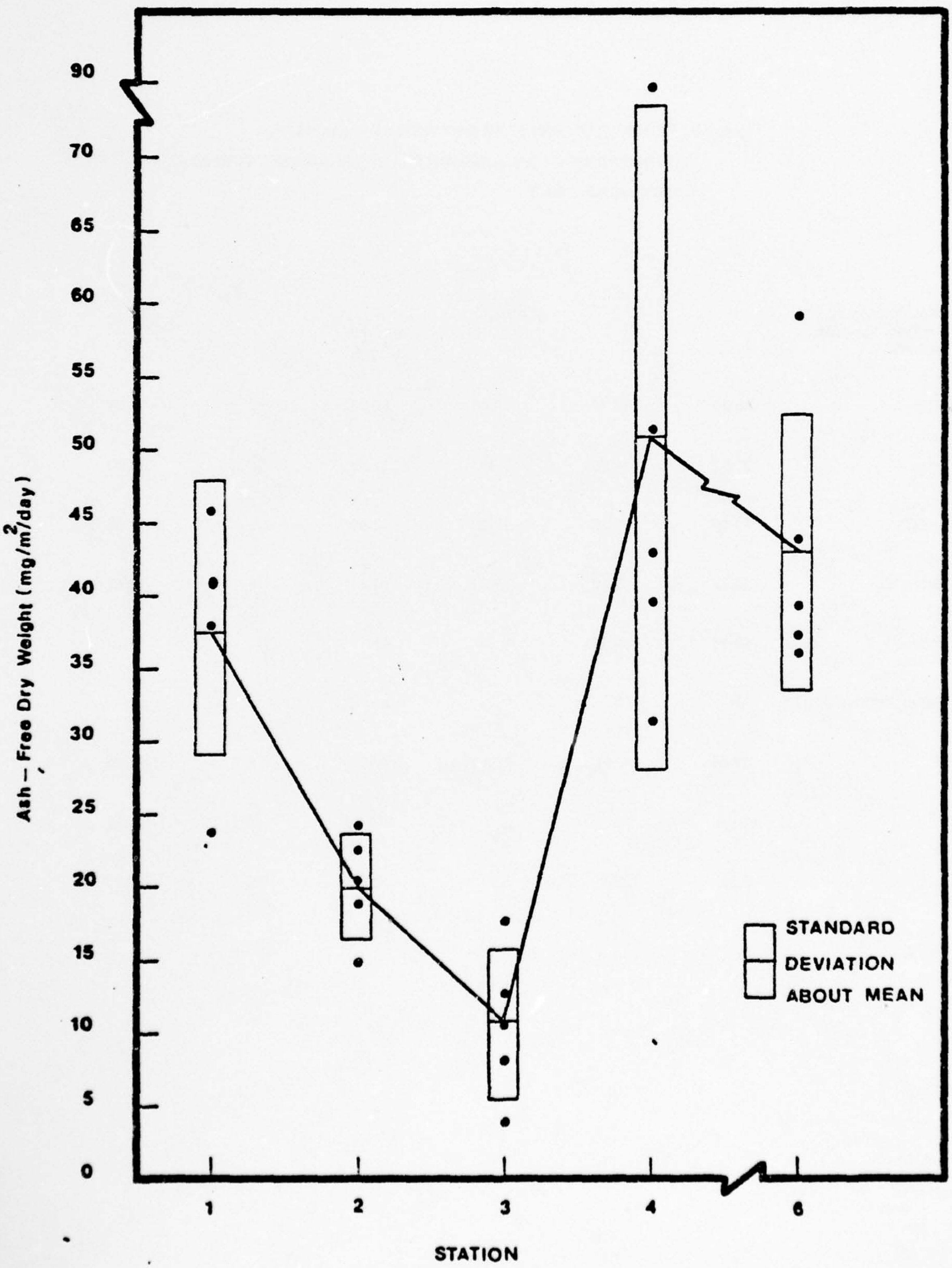
* no sample

Table 38. PERIPHYTON ASH-FREE DRY WEIGHT (mg/m$^2$/day).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA.
MAY - JUNE, 1975

| Slide Position in Artificial Substrate Sampler | STATION 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Slide 1 | 45.68 | 18.71 | 10.46 | 39.63 | NS* | 59.07 |
| Slide 4 | 23.67 | 14.86 | 3.85 | 31.37 | NS | 36.00 |
| Slide 7 | 40.18 | 22.56 | 12.66 | 42.93 | NS | 43.88 |
| Slide 10 | 37.98 | 20.36 | 17.61 | 89.71 | NS | 37.13 |
| Slide 13 | 40.18 | 24.22 | 8.26 | 51.18 | NS | 39.38 |
| Number of days | 46 | 46 | 46 | 46 | | 45 |
| $\bar{x}$ | 37.54 | 20.14 | 10.57 | 50.96 | NS | 43.09 |
| $s^2$ | 68.19 | 13.12 | 26.11 | 519.56 | NS | 88.88 |
| s | 8.26 | 3.62 | 5.11 | 22.79 | NS | 9.43 |

* no sample

FIGURE 27 Periphyton Ash–Free Dry Weight (mg/m²/day) from Five Replicate Artificial Substrates. Radford Army Ammunition Plant, New River, Virginia. May–June 1975



decrease at station R-3. A drastic shift then occurred where there was nearly a five-fold increase in mean ash-free dry weight at station R-4. Between station R-4 and R-6 there was nearly a 17 percent decrease in the mean ash-free dry weight.

Chlorophyll a (May-June) -
The trend of periphyton chlorophyll a measured from artificial substrates was nearly identical to that observed for ash-free dry weight during May-June, 1975. There was a slight increase in mean chlorophyll a levels between station R-1 and R-2. This may be exaggerated due to one extreme value at station R-2 which was much different from the other four replicates (Table 40; Figure 28 ). If the value of slide number 9, station R-2, is ignored the mean chlorophyll a ($mg/m^2$/day) at this station would be 0.09 rather than 0.25 (Table 40). If this was true then there would be a 57 percent decrease in chlorophyll a between stations R-1 and R-2 (Tables and 40 Figure 28 ). This would be very similar to the trend of ash-free dry weight as seen previously.

Using a mean chlorophyll a value of 0.09 $mg/m^2$/day at station R-2, there was very little change at station R-3 (0.12 $mg/m^2$/day) (Table 40). There was a three-fold increase in chlorophyll a as $mg/m^2$ or $mg/m^2$/day between station R-3 and R-4. Between station R-4 and R-6 there was an 8 percent decrease in chlorophyll a levels (Tables 39 and 40; Figure 28 ).

Autotrophic Index (May-June) -
The level of the autotrophic index was highest at station R-1 (177) and decreased through stations R-2 and R-3 with values of 82 and 89, respectively (Table 41 ). A value of 135 was calculated at station R-4 with a slight decrease to a level of 124 at station R-6. This suggests greater heterotrophic, i.e., non-algal, periphyton communities at stations R-1, R-4, and R-6. This is using a value of 100 as being the cut-off between heterotrophism and autotrophism.

Table 39 PERIPHYTON CHLOROPHYLL a (mg/m$^2$).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA.
MAY - JUNE, 1975

| Slide Position in Artificial Substrate Sampler | STATION 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Slide 3 | 6.31 | 3.05 | 4.55 | 18.70 | NS * | 18.38 |
| Slide 6 | 9.63 | 2.92 | 3.62 | 21.70 | NS | 17.23 |
| Slide 9 | 12.86 | 40.50 | 5.66 | 2.70 | NS | 10.00 |
| Slide 12 | 11.27 | 4.39 | 9.46 | 12.34 | NS | 11.33 |
| Slide 15 | 8.68 | 5.47 | 3.75 | 30.84 | NS | 21.10 |
| Number of days | 46 | 46 | 46 | 46 | | 45 |
| $\bar{x}$ | 9.75 | 11.27 | 5.41 | 17.26 | NS | 15.61 |
| $s^2$ | 6.244 | 268.165 | 5.79 | 110.601 | NS | 22.55 |
| s | 2.50 | 16.38 | 2.41 | 10.52 | NS | 4.75 |

* no sample

Table 40. PERIPHYTON CHLOROPHYLL a (mg/$m^2$/day).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA.
MAY - JUNE, 1975

| Slide Position in Artificial Substrate Sampler | STATION | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Slide 3 | 0.14 | 0.07 | 0.10 | 0.41 | NS * | 0.41 |
| Slide 6 | 0.21 | 0.06 | 0.08 | 0.47 | NS | 0.38 |
| Slide 9 | 0.28 | 0.88 | 0.12 | 0.06 | NS | 0.22 |
| Slide 12 | 0.24 | 0.10 | 0.21 | 0.27 | NS | 0.25 |
| Slide 15 | 0.19 | 0.12 | 0.08 | 0.67 | NS | 0.47 |
| Number of days | 46 | 46 | 46 | 46 | | 45 |
| $\bar{x}$ | 0.21 | 0.25 | 0.12 | 0.38 | NS | 0.35 |
| $s^2$ | 0.003 | 0.13 | 0.003 | 0.052 | NS | 0.011 |
| s | 0.054 | 0.356 | 0.052 | 0.228 | NS | 0.106 |

* no sample

FIGURE 28. Periphyton Chlorophyll a (mg/m$^2$/day) from Five Replicate Artificial Substrates. Radford Army Ammunition Plant. New River, Virginia.

May—June 1975

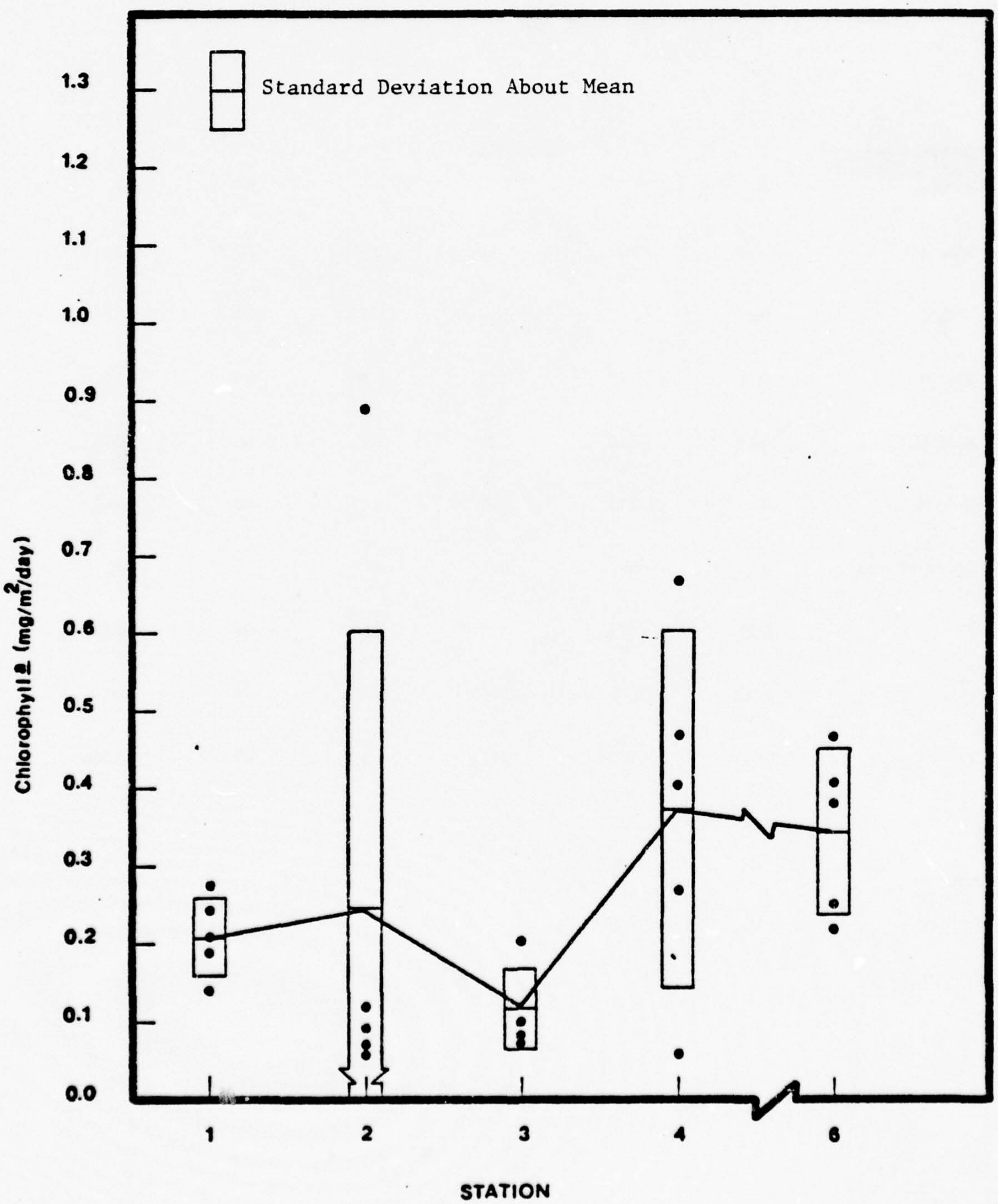


Table 41 PERIPHYTON AUTOTROPHIC INDEX. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE 1975.

| | Station | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| *Autotrophic Index | 177.08 | 82.21 | 89.84 | 135.82 | NS* | 124.23 |

*Autotrophic Index was calculated from the means of five values ash-free dry weight (mg/m$^2$) and five values chlorophyll a (mg/m$^2$) from each station.

Table 42. PERIPHYTON CHLOROPHYLL BEFORE ACIDIFICATION: AFTER ACIDIFICATION RATIO, RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE 1975.[1]

| Slide position in | Station | | | | | |
|---|---|---|---|---|---|---|
| Artificial Substrate Sampler | 1 | 2 | 3 | 4 | 5 | 6 |
| Slide 3 | 1.70 | 1.67 | 1.71 | 1.63 | NS* | 1.62 |
| Slide 6 | 1.68 | 1.69 | 1.65 | 1.65 | NS | 1.63 |
| Slide 9 | 1.67 | 1.39 | 1.60 | 1.27 | NS | 1.61 |
| Slide 12 | 1.37 | 1.63 | 1.72 | 1.38 | NS | 1.63 |
| Slide 15 | 1.36 | 1.64 | 1.67 | 1.35 | NS | 1.66 |
| $\bar{x}$ | 1.55 | 1.60 | 1.67 | 1.45 | NS | 1.63 |
| $s^2$ | 0.03 | 0.01 | 0.002 | 0.03 | NS | 0.0004 |
| $s$ | 0.17 | 0.12 | 0.048 | 0.17 | NS | 0.02 |

[1] Ratios of 1.7 are considered free of pheophytin and a ratio of 1.0 indicates pheophytin in the absence of chlorophyll.

* No Sample

The algal portion of these periphytic communities collected from artificial substrates was considered as living and viable. This was determined through the use of the "b/a" ratio to indicate the presence of pheophytin. At all stations the mean ratio was greater than 1.45, with levels of 1.7 indicating communities free of pheophytin (Table 42). The absence of pheophytin suggests the viability of the algal portion of the periphyton community giving reliability to the autotrophic index.

## Discussion of Results (May-June, 1975)

### Species Occurrence -

Diatom dominance on artificial substrates (May-June) - The diatom community sampled on artificial substrates showed important trends in the area of stations R-2, R-3, and R-4. It is these stations which are in closest proximity to the industrial waste outfalls from the nitroglycerin NO #2 Area. Diatom species diversity decreased significantly at stations R-2 and R-3 and then increased to a maximum at station R-4.

Table 43. ANALYSIS OF VARIANCE OF DIATOM SPECIES DIVERSITY

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 24 | 6.74 | | |
| Treatment (between) | 4 | 5.58 | 1.40 | 24.08* |
| Error (within) | 20 | 1.16 | 0.06 | |

F (0.95) = 2.87
*significant variation

The analysis of variance test (Table 43 ) indicates that the observed shifts in diatom species diversity were significant on artificial substrates.

Furthermore stations R-1 and R-6, the reference and recovery zone stations respectively, had very similar diatom species associations. Stations R-2 and R-3, which had the lowest diatom species diversity, likewise were highly similar. Station R-4, with its high diversity was more similar to stations R-1 and R-6, and was most different from stations R-2 and R-3. The truncated normal curves constructed for these stations indicate normal to slightly organic conditions which is defined by lower mode height and curves extending over more intervals.

These trends do not relate closely with the chemical characteristics and variations observed in the New River during May-June, 1975. The New River is characterized as a soft water, neutral river, having a hardness of 20-40 mg/l Ca $CO_3$ and an average pH of about 7.5 (refer to Chemistry Results). No parameter underwent drastic or significant variations in the area of stations R-2 and R-3 which would account for the marked decrease in diatom species diversity. On one occasion it was discovered that there was a drastic diurnal shift in pH which dropped three to four pH units over a 24 hour period. This occurred during a diurnal study during the spring survey and the source is uncertain. It is also not known if this was a accidental occurrence, or if it was a routine occurrence. No diurnal pH shift was recorded on later occasions. This single event may have been responsible for the loss of species of stations R-2 and R-3.

Between stations R-2, R-3, and R-4 there was an increase in diversity, i.e., a recovery, and this trend parallels small increases in Kjeldahl-nitrogen, nitrate-nitrogen, and total phosphorus. From the chemistry data it is suspected that nitrate increases could have localized affects in the New River. Other parameters remained somewhat constant between stations (see Chemistry results). Station R-4 was closely positioned to recieve the discharge of Outfall No. 20 plus the additive affect of Outfall Nos. 18 and 19 further upstream. Referring to the results and discussion of the Chemistry section in this report, it was shown that increased levels of TOC, nitrogen, and nitroglycerin occurred with distance downstream from the reference station. The increase of TOC is not directly related to waste

discharge. Nutrient and nitrogen increases quite possibly had a stimulatory affect on the periphyton, especially at station R-4 due to its close proximity to the discharges.

Species dominance at each station was comprised of an Achnanthes/Cocconeis complex accounting for as much as 95 and 97 percent of the total diatom species association at some stations. This complex predominated at all stations (see Biology results section). The species of Achnanthes which were common occur in waters of pH 4.3 - 9.2, with optimum growth at pH 6.5 - 7.5 [41]. These species of Achnanthes are also indifferent to salts (less than 500 mg/l). The common species of Cocconeis also occur in the pH range characteristic of the New River and are indifferent to small amounts of salts. The occurrence of diatom species found on artificial substrates in the New River were typical of soft, neutral waters. Furthermore there were no major shifts in the species association at any station and no species variations occurred which could be correlated with industrial waste discharge from the NG #2 Area.

Occurrence of non-diatoms on artificial substrates (May-June) - It was shown that the non-diatom algae comprised a very small percentage of the periphyton algae species associations. The pennate diatoms were the dominant algal form at all stations, occurring at a frequency of 57 to 88 percent. Non-diatom algae were most common at station R-1, decreased in frequency of occurrence through station R-3, and slightly increased in occurrence at stations R-4 and R-6. The blue-green algae, Chroococcus dispersus (Keissl.) Lemm. and C. minor Kuetz. were the most frequent, yet they were only occasionally common. The non-diatom algae were a relatively unimportant segment of the periphyton community and were not affected by the waste discharges in the area of the New River studied.

Diatom dominance on natural substrates (May-June) - As shown in the previous results section, combined species diversity was more representative of the naturally occurring periphyton community than the mean species diversity. Combined species diversity on natural substrates paralleled the trend seen on artificial substrates although diversity values were two to five times greater on natural substrates. Variations were most obvious and extensive above and below station R-4; station R-4 having the highest species diversity.

The trends of diversity on artificial substrates appeared to be greater or more significant than on natural substrates. Since the species associations occurring on natural substrates is more complex, i.e., diverse, and the dominant species occur at a lower percentage, the affects of the industrial wastes are not as evident as reflected by artificial substrate comparisons. The species association occurring on artificial substrates is less complex and the dominant species occurred at a higher frequency. Therefore, physico-chemical factors causing minor changes in the species association had greater impact on diversity and similarity comparisons. Thus, affects seen on artificial substrates may be somewhat more obvious, however, it was shown that these affects were short term and there was recovery within the study area.

Species similarity was greater between station R-5 and R-6. This is to be expected of near adjacent locations particularly if physico-chemical conditions remain constant[26]. Reference to the water chemistry results of this report indicate similar conditions between these stations with small differences in total solids, COD, TOC, total Kjeldahl nitrogen, total phosphorus, chloride, cadmium, chromium, and nitroglycerin. For the most part adjacent station pairs e.g., R-1/R-2, R-2/R-3, R-3/R-4, R-4/R-5, and R-5/R-6, most always had diatom associations near the 50 percent level of similarity. Since no station pair or pairs had extremely low similarities it can be assumed that there were no adverse affects caused by physico-chemical variations in this area of the New River.

Observed differences in the diatom species associations between the six study stations were not great. No single species was abundant nor varied to extremes between stations. The common species complex included: *Achnanthes acares* Hohn & Hellerm. sp. nov. var. *acares*, *A. linearis* var. *pusilla* Grun., *A. minutissima* Kuetz. var. *minutissima*., *Navicula mutica* var. *undulata* (Hilse) Grun., *N. mutica* var. *tropica* Hust., *N. gregaria* Donk var. *gregaria* *Rhoicosphenia curvata* (Kuetz.) Grun. var. *curvata*, *Nitzschia parvula* Lewis var. *parvula*, and *N. palea* (Kuetz.) W. Sm. var. *palea*. These species are typically found in circumneutral, soft to hard waters[32,41], not different from the New River.

Ash-Free Dry Weight (May-June) -

Table 44. ANALYSIS OF VARIANCE OF ASH-FREE DRY WEIGHT ($mg/m^2/day$)

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 24 | 8424.53 | | |
| Treatment (between) | 4 | | 1390.27 | 9.71* |
| Error (within) | 20 | 286.45 | 143.17 | |

F (0.95) = 2.87
*significant variation

Similar to the trends of diatom species diversity, periphyton ash-free dry weight ($mg/m^2/day$) decreased through the area of stations R-2 and R-3. This was followed by a substantial increase at station R-4. An analysis of variance test on these data (Table 44) indicates that the observed variations were significant at the 95 percent level of confidence. Little difference was shown between the reference station (R-1) and the two stations furthest downstream (R-4 and R-6).

Chlorophyll a (May-June) -

Table 45. ANALYSIS OF VARIANCE OF CHLOROPHYLL a ($mg/m^2/day$)

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 24 | 1.0 | | |
| Treatment (between) | 4 | 0.22 | 0.05 | 1.39* |
| Error (within) | 20 | 0.78 | 0.04 | |

F (0.95) = 2.87
*no significant variation

It was shown in the previous section (Biology, Periphyton Results) that a similar trend was observed between diatom species diversity, ash-free dry weight, and chlorophyll. Of these, least variable was chlorophyll a ($mg/m^2/day$), which was shown to have an insignificant variation at the 95 percent level confidence (Table 45).

Autotrophic Index (May-June) -

Data for this index was gathered from mean ash-free dry weight and mean chlorophyll a values collected from artificial substrates. The autotrophic index, a measure of autotrophism or heterotrophism, paralleled the trends discussed previously. This index varies as a function of ash-free dry weight and chlorophyll a singly or in combination. Values of 100 or less have been used to indicate "clean water", autotrophic conditions[37]. On the other hand values greater than 100 reflect organic conditions, "pollution", and heterotrophic species associations[37].

Variation of the autotrophic index in the study area of the New River was greatest between stations R-1 and R-4. That is, stations R-1, R-4, and R-6 indicated heterotrophic conditions while stations R-2 and R-3 reflected

autotrophic conditions. Since chlorophyll a levels were somewhat constant between the stations, the disproportionate variations in ash-free dry weight were responsible for the changes in the autotrophic index.

First thoughts are to determine the source of the ash-free dry weight. If this mass is of a non-viable nature, i.e, organic detritus, then the autotrophic index will erroneously reflect heterotrophic conditions greater than reality. Without measuring ATP (adenosine triphosphate), and correlating this with chlorophyll and biomass, it may not be possible to accurately predict the reliability of the autotrophic index. However, correlation of ash-free dry weight with total solids, total volatile solids, COD, and total organic carbon may add confidence to this index.

High levels of volatile solids and organic carbon would subject the artificial substrates, and therefore the periphyton biomass, to highly organic conditions which would favor heterotrophic species, i.e., bacteria, yeasts, fungi, and protozoans. There were no correlations favoring organic conditions of one station over another. Total suspended solids were similar at all stations, total solids varied but opposite of ash-free dry weight, and total organic carbon remained low above station R-6 where it increased four-fold. This did not produce a corresponding increase in the ash-free dry weight or autotrophic index. BOD, COD, and TOC data indicates that the carbon compounds discharged in the study area are not subject to biological oxidation.

The periphyton data collected during May-June, 1975, indicates changes in this microcommunity in the area of stations R-2, R-3, and R-4. No adverse affects were seen on the species complex of diatoms. Although species diversity decreased this was a short-term affect and recovery was rapid. Most noticeable was the variation in periphyton biomass (ash-free dry weight). Chlorophyll did not vary significantly indicating that observed affects did not necessarily influence the algal portion of the periphyton. Primary production was therefore not inhibited. Non-algal biomass appeared to vary to the greatest extent and other methods must be applied

to determine the significance of these variations. In the area of the New River studied, in reference to the nitroglycerin No. 2 area, possible affects of waste discharge on periphyton was limited to a small area and recovery was observed within a short distance during May-June 1975.

PERIPHYTON

Results (October - November, 1975)

Species Occurrence -

Diatom dominance on artificial substrates (October-November) - During the fall survey diatom species data was gathered from three replicate samples at each station rather than five replicates as seen during the spring survey. Tables 46 and 47 and Figure 29 indicates the level of variance between replicate samples and the trend of species diversity and species evenness between the stations. Data is presented from only four of the six study stations since the artificial substrate samplers were lost at two stations (R-2 and R-5). There was close replication in terms of species diversity at only one station, that being station R-4 (Table 46 and Figure 29). The degree of replication is further verified through the use of the Pinkham and Pearson coefficient of similarity. Using this means of analysis the following was noted:

1. At station R-1 the three replicate samples were similar at or above the 52 percent level (Figure 30). Two of the replicates were similar above the 78 percent level. This is also reflected by the variance in species diversity (Figure 29). Exclusion of the most different value would result in a somewhat lower mean species diversity at this station.
2. Species similarity at station R-3 was not below 80 percent (Figure 31). Two sample replicates were similar at the 85 percent level. This higher level of similarity was reflected by a lower level of variance in species diversity (Figure 29).
3. There was very little variance between sample species diversity at station R-4 (Figure 29). Between the three replicates at this station, two had species associations above the 90 percent level while the third sample was similar to this pair at 80 percent (Figure 32).

Table 46. SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES. RADFORD ARMY AMMUNITION PALNT, NEW RIVER, VIRGINIA. OCTOBER, NOVEMBER, 1975.

| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.03 | NS* | 1.64 | 0.93 | NS | 2.53 |
| 2 | 2.10 | NS | 1.05 | 0.78 | NS | 1.18 |
| 3 | 0.82 | NS | 1.18 | 0.87 | NS | 1.28 |
| x | 1.31 | NS | 1.29 | 0.86 | NS | 1.66 |
| $s^2$ | 0.47 | NS | 0.10 | 0.01 | NS | 0.57 |
| s | 0.68 | NS | 0.32 | 0.08 | NS | 0.75 |

Table 47. SHANNON-WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES. RADFORD ARMY AMMUNITION PALNT, NEW RIVER, VIRGINIA. OCTOBER, NOVEMBER, 1975.

| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 0.45 | NS* | 0.49 | 0.36 | NS | 0.70 |
| 2 | 0.64 | NS | 0.42 | 0.56 | NS | 0.47 |
| 3 | 0.39 | NS | 0.49 | 0.45 | NS | 0.47 |
| x | 0.49 | NS | 0.47 | 0.45 | NS | 0.55 |
| $s^2$ | 0.016 | NS | 0.002 | 0.010 | NS | 0.017 |
| s | 0.128 | NS | 0.041 | 0.099 | NS | 0.131 |

*No sample

Figure 29. RAAP PERIPHYTON- DIVERSITY FOR ART. SUB. (OCT-NOV 75)

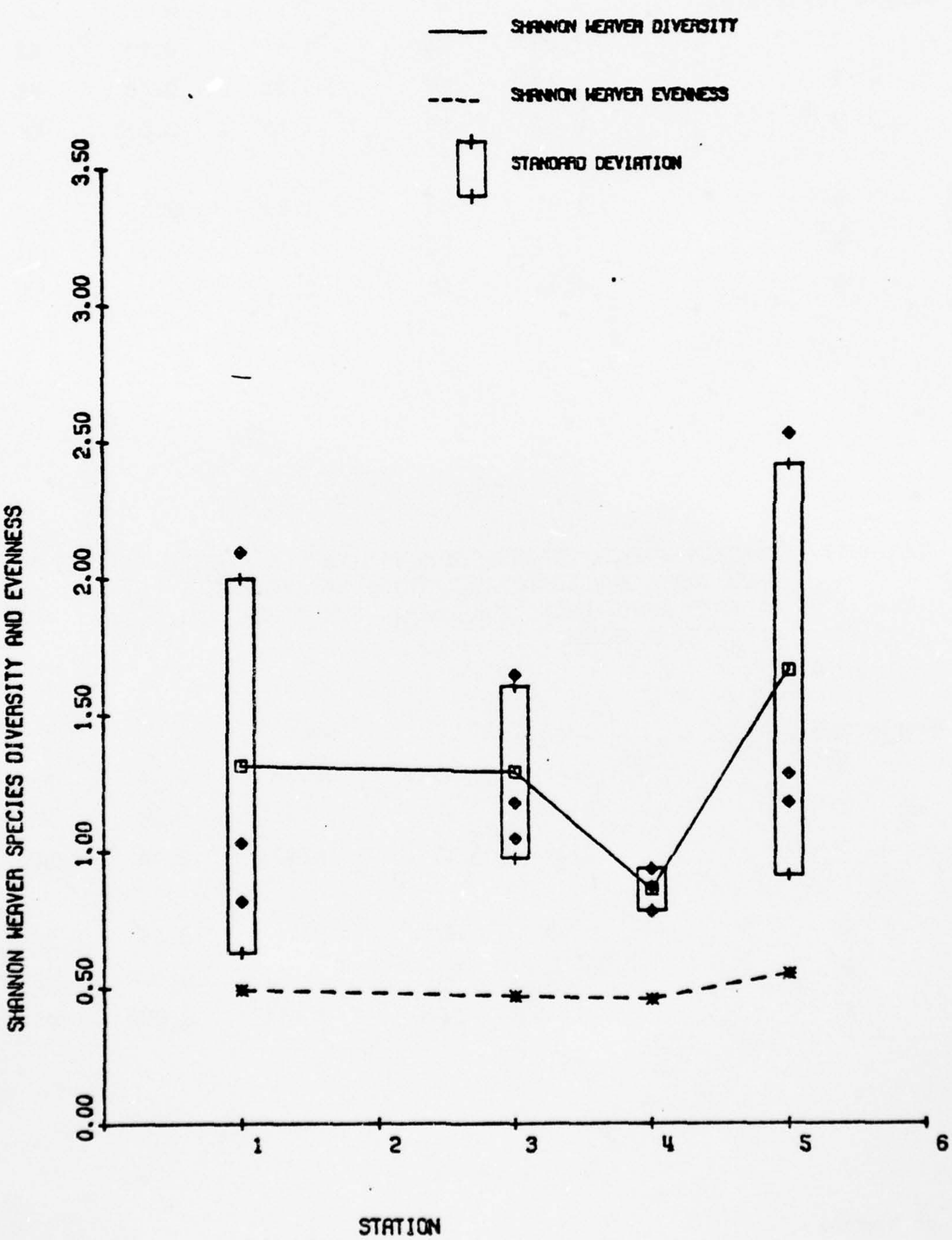


Figure 30.

STATION R1-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

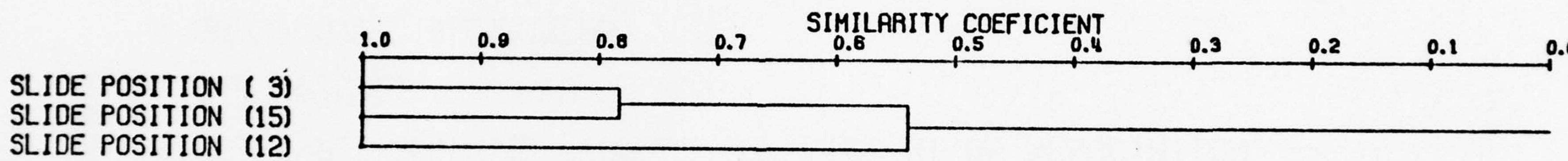


Figure 31

STATION R3-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT

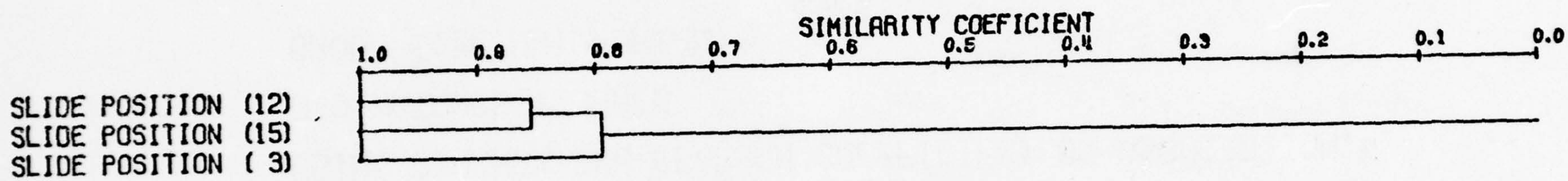


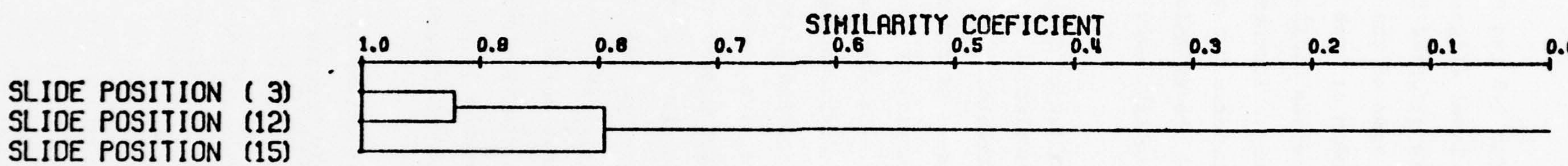
Figure 32.

STATION R4-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT



4. At station R-6 two replicate samples were similar at the 88 percent level (Figure 33). It should be noted that these species data were gathered from the same collection. This was necessary because some of the slides in the artificial substrate samplers were broken or lost before they were collected. The third replicate was similar to the previous pair of samples at only 42 percent. Furthermore, species diversity (Figure 29) was quite variable between these three units of species data. Likewise the exlusion of the most different value would result in a slightly lower mean species diversity.

Through the application of species diversity and coefficient of similarity to the replicate samples at every station, a better description of the diatom community structure was acheived. The degree of sample replication, i.e., species likeness as shown by the coefficient of similarity, indicates whether or not a sufficient sample was taken to adequately describe the existing community. It was shown that most often one of the three replicate samples were quite different from the other two samples, and the presence or absence of its species data had little effect on the overall trend of community structure, i.e., species diversity. In actuality, this practice of excluding the most different replicate at each station would serve to slightly reduce the mean species diversity at only two stations, R-1 and R-6, and would therefore reduce the overall variation in the trend of mean species diversity between stations. The inclusion of all replicate samples on a combined basis at each station provided a broader species complex from which station-to-station comparisons were made. This approach included the occurrence of many rare and uncommon species and altered the calculated mean species diversity at two of the four stations studied.

Mean diatom species diversity collected from artificial substrates did not change significantly between the four stations sampled. Mean diversity was the same at stations R-1 and R-3, 1.31 and 1.29 respectively, and decreased slightly to 0.86 at station R-4. Highest diversity (1.66) occurred at station R-6 (Figure 29). Species evenness was nearly identical at the four stations.

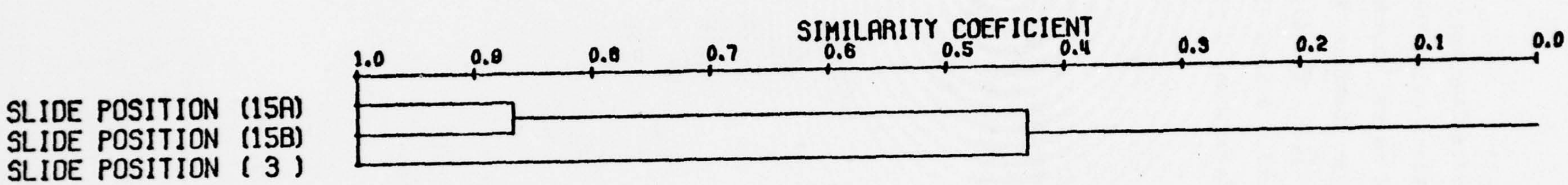
Figure 33.

STATION R6-RAAP PERIPHYTON-COMPARISON OF ART. SUB. REPS. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT



When diatom species data from replicate samples was combined and then compared between stations using the coefficient of similarity, the four stations were grouped as two distinct pairs. Stations R-1 and R-6, the extreme upstream and downstream stations, were paired at the 75 percent level (Table 48 and Figure 34). The adjacent stations, R-3 and R-4, were similar at the 83 percent level. Diatom species associations at all four stations were similar at not less than 70 percent (Figure 34).

Table 48. COEFFICIENT OF SIMILARITY COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED REPLICATES AT EACH STATION, ARTIFICIAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER - NOVEMBER, 1975

| Stations | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | |
| 2 | NS* | NS | | | | |
| 3 | 0.715 | NS | 1.000 | | | |
| 4 | 0.650 | NS | 0.833 | 1.000 | | |
| 5 | NS | NS | NS | NS | NS | |
| 6 | 0.751 | NS | 0.759 | 0.669 | NS | 1.000 |

*No sample

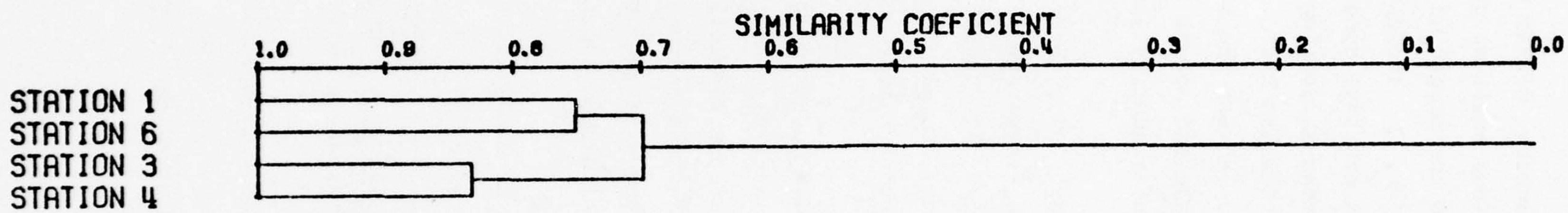
Figure 34.

RAAP PERIPHYTON-STATION COMPARISON OF ART. SUB.-COMB. REP. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES IGNORED

GROUP SIZE UNIMPORTANT



Application of the truncated normal curve to the periphyton data[28] revealed that at three of the four stations the height of the mode was in the first or second interval and the length of these curves extended into the tenth interval (Figures 35, 36 , 37 , and 38 ). At stations R-1 and R-4 the height of the mode was at six and five species respectively (Figures 35, and 37 ). The highest mode occurred at station R-3 which had a mode height at 10 species (Figure 36 ). Station R-6 did not have a well defined mode, occurring at about three species between the second and fourth intervals (Figure 36). The pattern of the truncated normal curves, although not extensively developed, indicate no adverse water quality in the study area.

During October-November, 1975, there were 30 diatom species recorded at station R-1. Of these, three species comprised 86 percent of the total association (Appendix X ). These were *Cocconeis placentula* var. *lineata* (Ehr.) V.H. (54 percent), *C. plancentula* var. *euglypta* (Ehr.) Cl. (27 percent), and *Achnanthes minutissima* Kuetz. var. *minutissima* (5 percent).

These same three species occurred at station R-3. *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. and *C. placentula* var. *lineata* (Ehr.) V.H. were very common at 40 and 45 percent respectively. *Achnanthes minutissima* Kuetz. var. *minutissima* was again occasional at five percent (Appendix X). Of 34 diatom species recorded at this station, these three species comprised 90 percent of the total diatom species complex.

A substantial decrease in number of species occurred at station R-4. Fifteen species were found at this station of which two species comprised 96 percent of the species association. *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. and *C. placentula* var. *lineata* (Ehr.) V.H. were very common at 50 and 46 percent respectively (Appendix X).

At station R-6 there were 19 species of which four were common or very common, comprising 85 percent of the total species complex. These were *Achnanthes linearis* var. *pusilla* Grun. and *A. minutissima* Kuetz. var. *minutissima*

FIGURE 35 Distribution of Diatom Community Collected on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.

October–November 1975

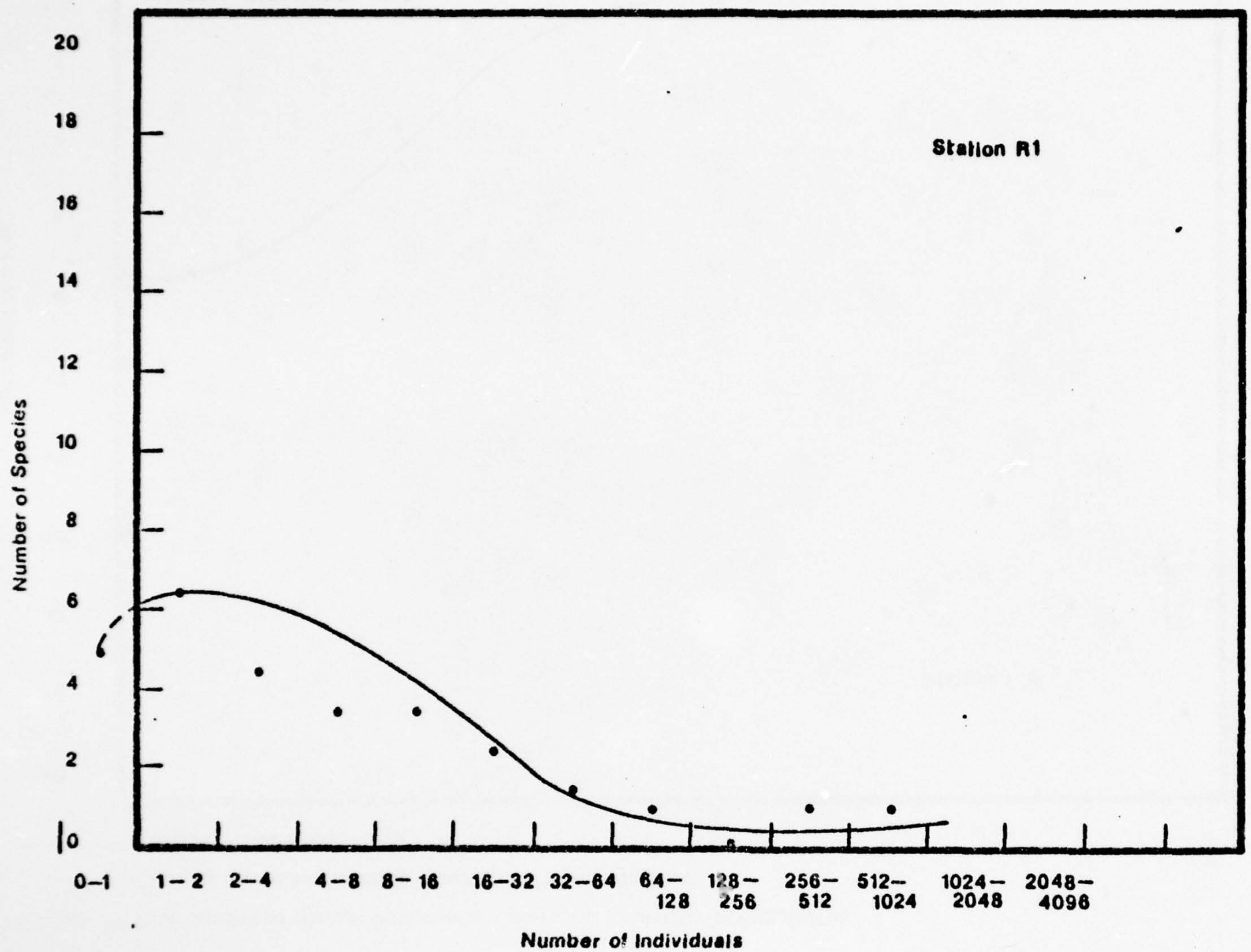


FIGURE 36 Distribution of Diatom Community Collected on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.
October—November 1975

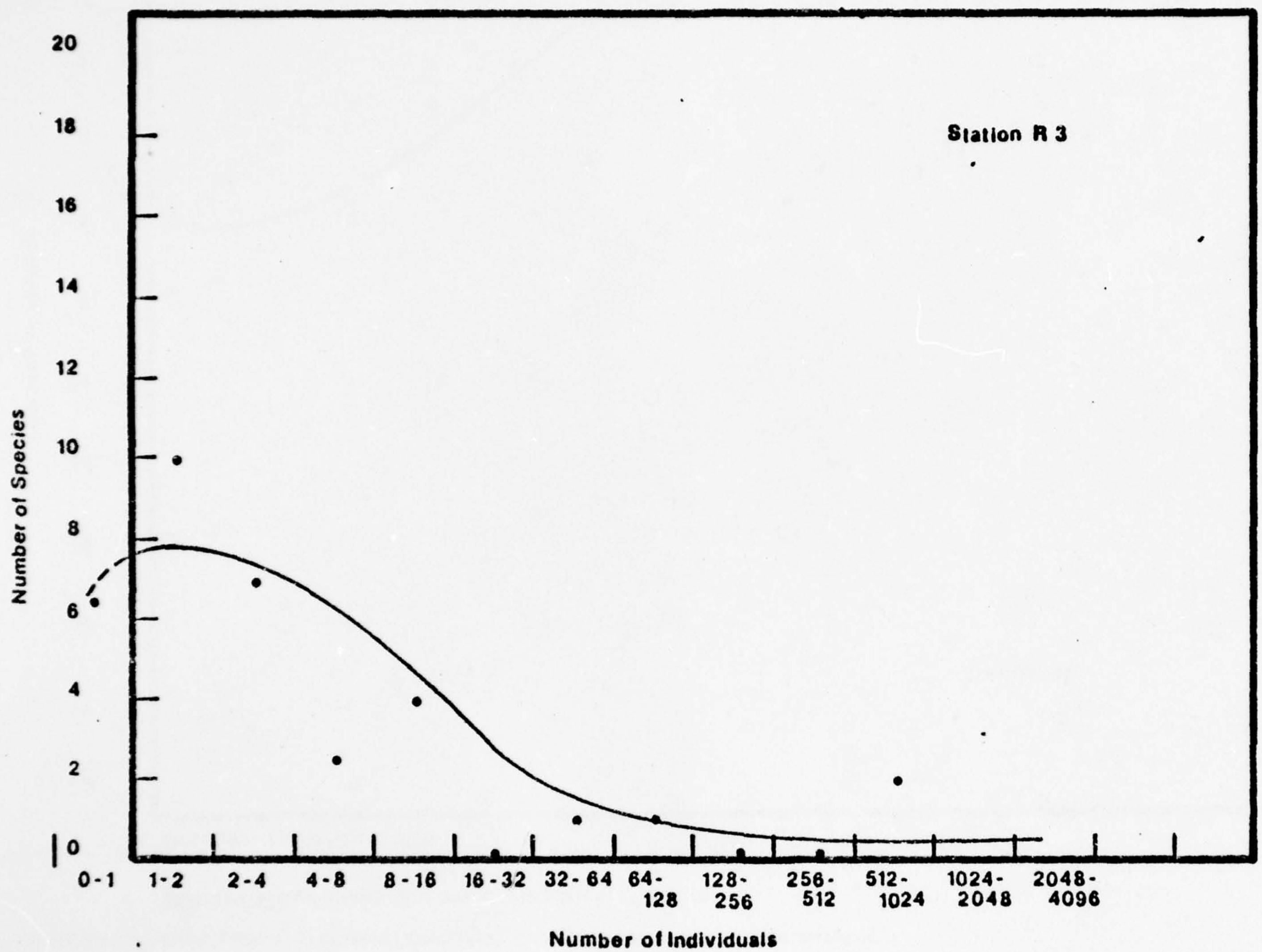
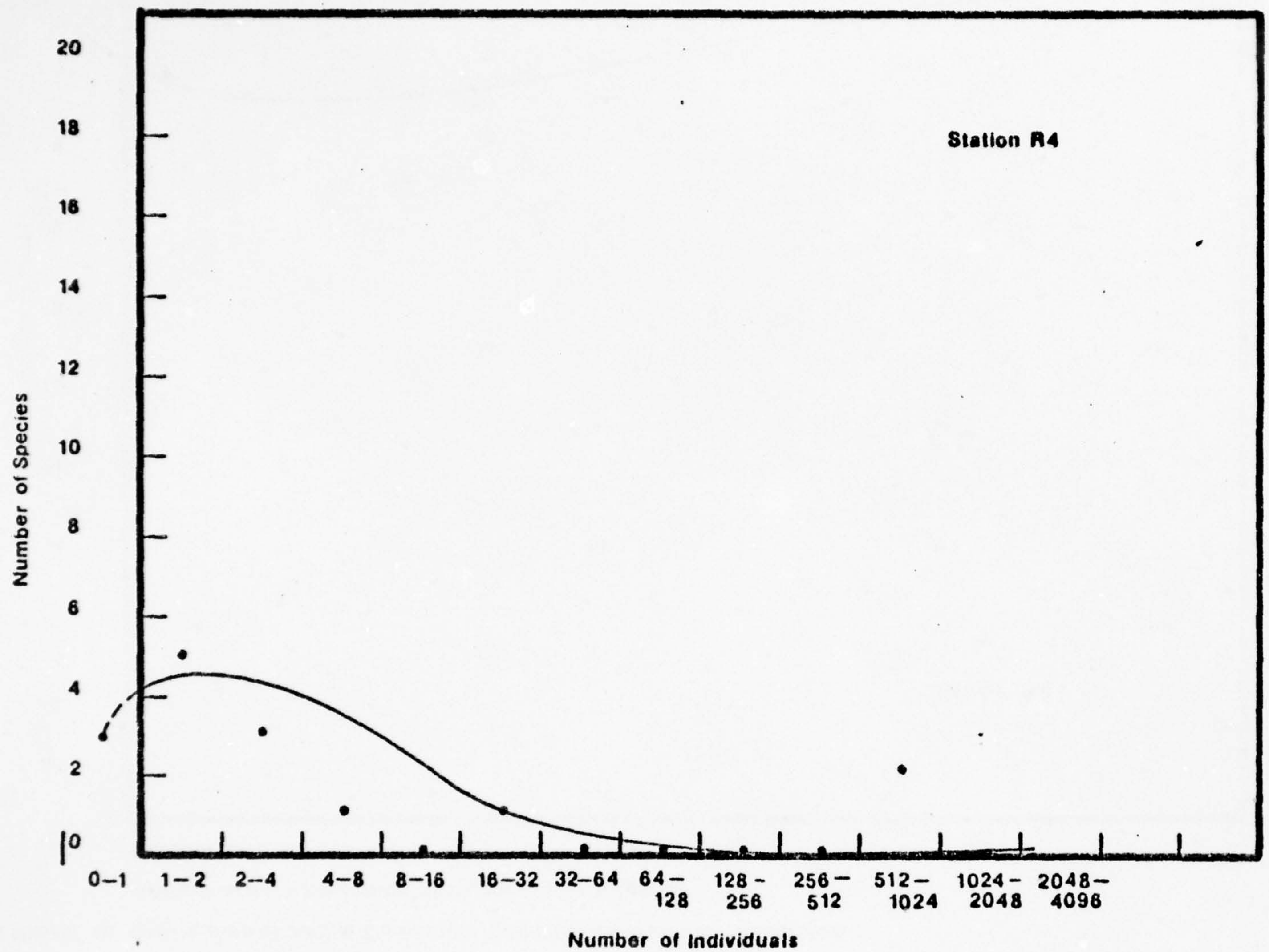


FIGURE 37 Distribution of Diatom Community Collected on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.
October - November 1975



AD-A036 777 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD, AND JOLIET ARMY AMMUNIT--ETC(U)
MAR 76 R L WEITZEL, R EISENMAN, J E SCHENK DAMD17-75-C-5046
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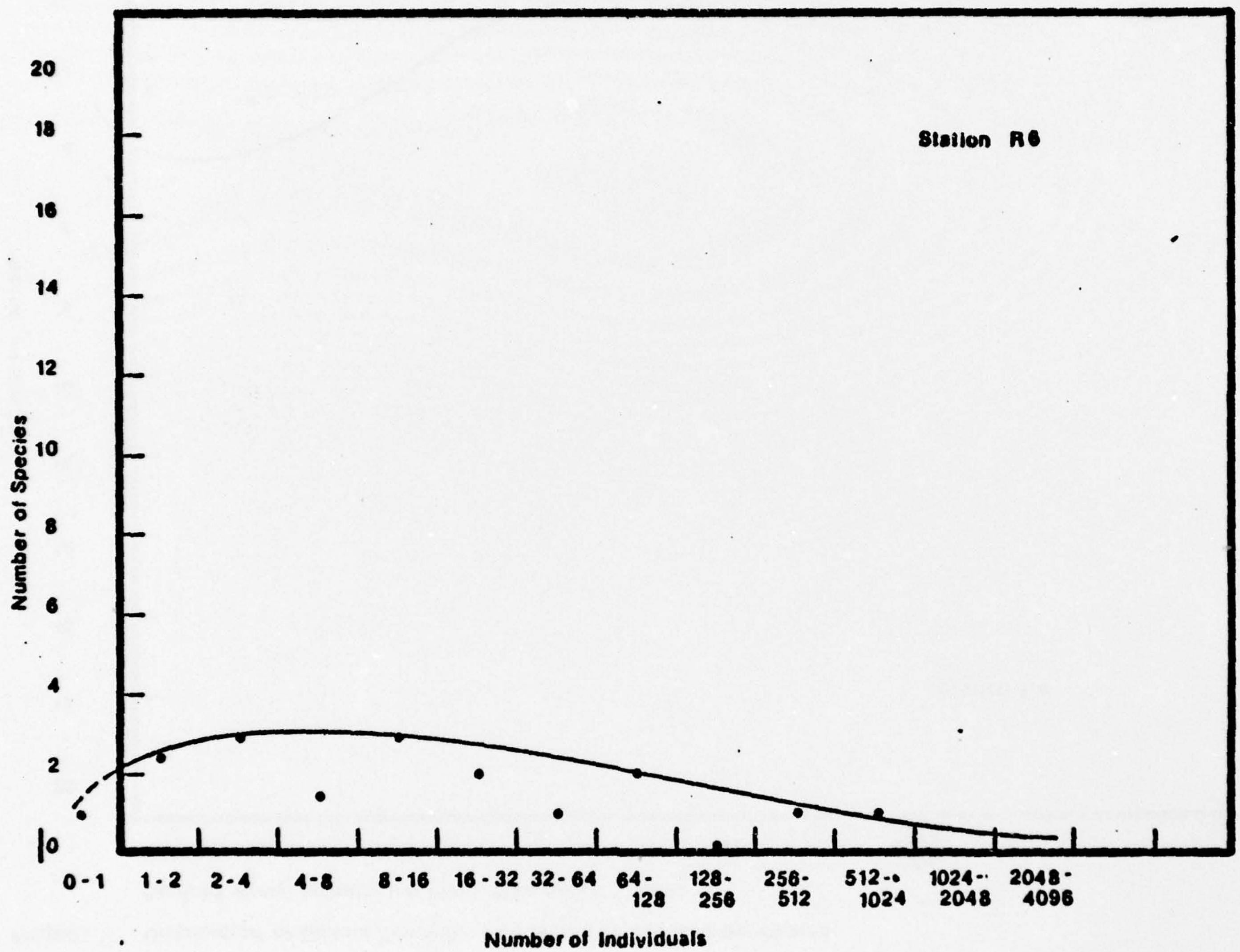
FIGURE 38 Distribution of Diatom Community Collected on Artificial Substrates.
Radford Army Ammunition Plant, New River, Virginia.
October 1975



(7 percent each), and Coccones placentula var. euglypta (Ehr.) Cl. (25 percent) and C. placentula var. lineata (Ehr.) V.H. (46 percent) (Appendix X).

There was great similarity between the stations in terms of dominant taxa where Cocconeis placentula var. euglypta (Ehr.) Cl. and C. placentula var. lineata (Ehr.) V.H. were always dominant. Differences in diatom community structure and similarity which occurred between the four sampling stations were the result of the occurrence, loss, and recurrence of uncommon and rare species most occurring at a frequency of less than one percent. The same dominant taxa were found at all stations with only slight variations in their relative frequency of abundance.

Diatom dominance on natural substrates (November) - Similar to the May-June survey, species diversity of diatom communities on natural substrates was two to three times greater than that found on artificial substrates. Furthermore the trend observed between stations was somewhat similar for species diversity on natural substrates during both surveys. Diatom diversity was lowest on wood surfaces at station R-3 (2.79) and station R-1 (2.88) (Table 49). Slightly higher diversity occurred at station R-2 (2.06). Highest diversity on wood surbstrates was found at station R-4 (3.35) while diversity at stations R-5 and R-6 were somewhat lower, 3.24 and 3.27 respectively (Table 49).

A slightly different trend was observed in diversity collected from rock substrates. Lowest diversity occurred at stations R-5 and R-6, 2.87 and 2.88 respectively (Table 49). Diversity on rock surfaces was similar (2.90) at station R-2. At stations R-1, R-3, and R-4 diversity was slightly higher at 3.07, 3.02, and 3.09 respectively (Table 49).

On neither substrate type, i.e., wood or rock surfaces, were there extreme variations in diatom species diversity between stations. Mean species diversity and evenness on natural substrates (Table 49 and 50 and Figure 40 ) were very similar at all six stations sampled. Stations R-1, R-2 and R-3 had near identical levels (2.9) followed by a slight increase in diversity at

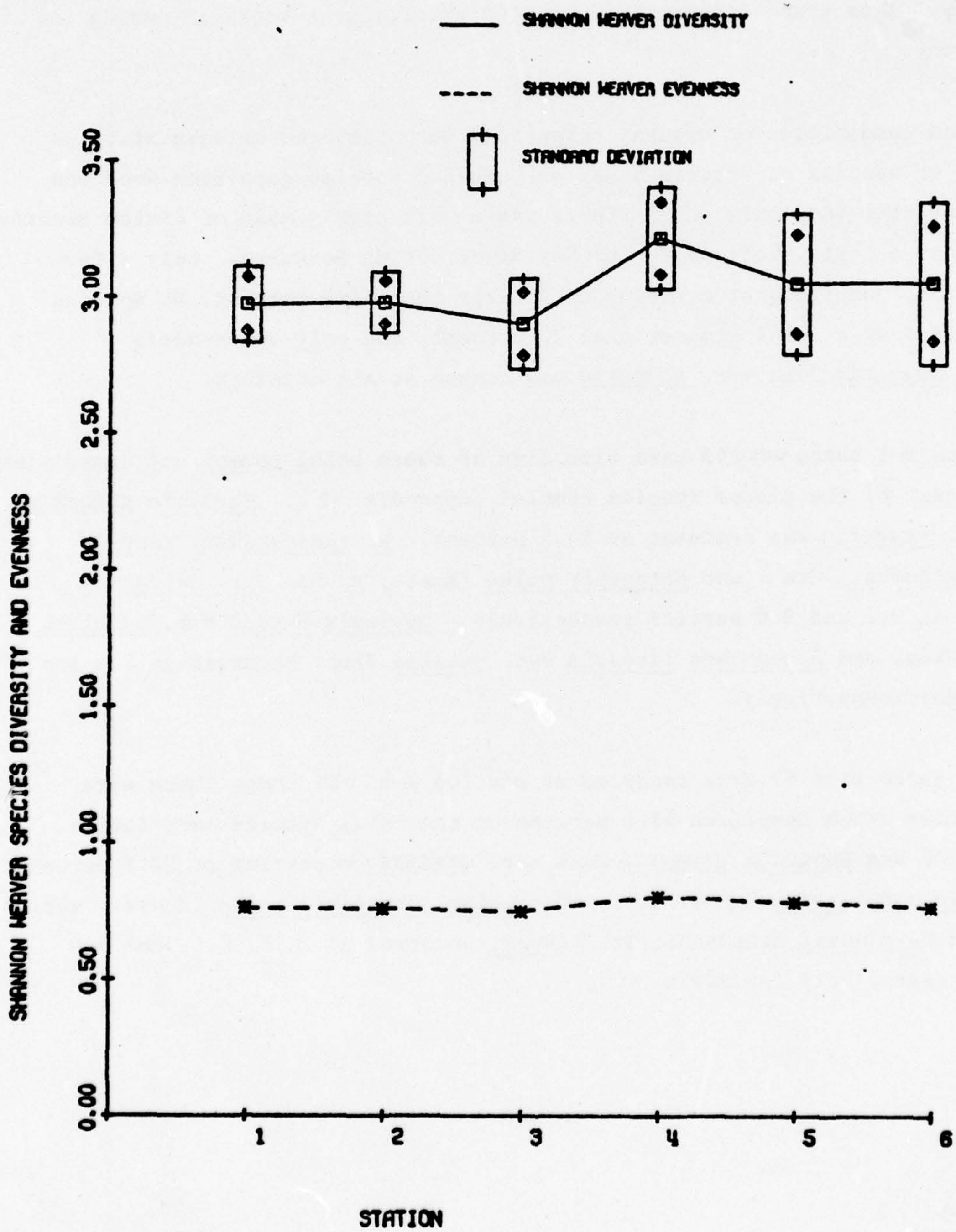
Table 15. SHANNON-WEAVER SPECIES DIVERSITY FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER- NOVEMBER, 1975

| Sample types | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| wood | 2.88 | 3.06 | 2.79 | 3.35 | 3.24 | 3.27 |
| rock | 3.07 | 2.90 | 3.02 | 3.09 | 2.87 | 2.88 |
| sediment | sample incomplete | | | | | |
| x | 2.97 | 2.98 | 2.90 | 3.22 | 3.05 | 3.07 |
| $s^2$ | 0.019 | 0.013 | 0.027 | 0.035 | 0.067 | 0.090 |
| s | 0.139 | 0.112 | 0.165 | 0.188 | 0.258 | 0.300 |

Table 16. SHANNON- WEAVER EVENNESS FOR PERIPHYTON DIATOMS COLLECTED FROM THREE NATURAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER, 1975

| Sample type | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| wood | 0.74 | 0.78 | 0.71 | 0.83 | 0.83 | 0.78 |
| rock | 0.79 | 0.74 | 0.79 | 0.78 | 0.74 | 0.75 |
| sediment | samples incomplete | | | | | |
| x | 0.76 | 0.76 | 0.75 | 0.80 | 0.78 | 0.76 |
| $s^2$ | 0.001 | 0.001 | 0.004 | 0.001 | 0.004 | 0.001 |
| s | 0.038 | 0.031 | 0.062 | 0.031 | 0.066 | 0.025 |

Figure 40. RAAP PERIPHYTON- DIVERSITY FOR NAT. SUB. (NOV. 75)



station R-4 (3.2). There was then a slight decrease to a common level (3.0) at stations R-5 and R-6. Although the trend was not identical between spring and fall surveys, it was common in that diatom diversity was greatest at station R-4. Furthermore the trend of species diversity on artificial substrates during the spring survey also showed station R-4 with highest diversity. This trend did not hold true on artificial substrates during the fall survey.

The diatom communities on natural substrates were compared between stations in terms of species occurrence based on combined species data from wood and rock substrates (Appendix XI). There was a very high number of diatom species recorded at all six stations in the New River during November. Only a few were common, occurring at a frequency greater than five percent. No species were present at a level greater than 30 percent, and only one species Navicula gregaria Donk var. gregaria was common at all stations.

At station R-1 there were 65 taxa with five of these being common and comprising 55.4 percent of the diatom species complex (Appendix XI). Navicula gregaria Donk var. gregaria was dominant at 24.5 percent. N. radiosa var. tenella (Breb. ex Kuetz.) Grun. and Nitzschia palea (Kuetz) W. Sm. var. palea occurred at 9.5 and 8.4 percent respectively. Navicula mutica var. undulata (Hilse) Grun. and Achnanthes linearis var. pusilla Grun. occurred at 7.4 and 5.6 percent respectively.

Likewise there were 65 taxa recorded at station R-2. Of these there were four species which comprised 48.1 percent of the total species association. Most common was Navicula gregaria Donk var. gregaria occurring at 22.5 percent. Achnanthes minutissima Kuetz. var. minutissima, Nitzschia palea (Kuetz.) var. palea and N. clausii Hantzschi var. clausii occurred at 12.5, 8.1, and 5.0 percent respectively (Appendix XI).

Sixty-two species were recorded at station R-3 with four species comprising 49.3 percent of the species complex. Navicula mutica var. undulata (Hilse) Grun., N. gregaria Donk var. gregaria and N. cincta (Ehr.) Ralfs var. cincta were common at 21.2, 11.2, and 6.8 percent respectively. Occurring at 10.1 percent was Nitzschia parvula Lewis var. parvula (Appendix XI ).

Of 69 diatom species at station R-4, four comprised 37 percent of the diatom community. Navicula gregaria Donk var. gregaria (14.8 percent) and N. cincta (Ehr.) Ralfs var. cincta (8.7 percent) were most common. Nitzschia palea (Kuetz.) W. Sm. var. palea and Achnanthes linearis var. pusilla Grun. occurred at 7.1 and 6.4 percent respectively (Appendix XI).

There were 61 taxa enumerated at station R-5 with five of these comprising 50.0 percent of the diatom population. Achnanthes linearis var. pusilla Grun. was most abundant at 14.7 percent while A. minutissima Kuetz. var. minutissima had an occurrence of 6.6 percent (Appendix XI ). Navicula gregaria Donk var. gregaria and N. minima Grun. var. minima were recorded at 10.3 and 9.6 percent respectively. Nitzschia palea (Kuetz.) W. Sm. var. palea occurred at a level of 8.8 percent.

The greatest number of taxa, 72, were recorded at station R-6. Four species were common, comprising 43.5 percent of the total diatom population. Achnanthes lineraris var. pusilla Grun. occurred at a frequency of 14.4 percent. Occurring at 10.2, 9.6, and 9.3 percent were respectively Nitzschia palea (Kuetz.) W. Sm. var. palea, Navicula gregaria Donk var. gregaria and Nitzschia clausii Hantzsch var. clausii (Appendix XI ).

When the species data gathered from natural substrates was combined at each station and then compared on a station-to-station basis it was found that all stations had similar associations near the 50 percent level (Table 51 and Figure 39 ). Furthermore the pairings were in an ideal fashion, i.e., adjacent stations were paired in order from upstream to downstream. Most similar were stations R-1 and R-2 (58 percent) followed by stations R-3 and R-4 being grouped with this pair. Stations R-5 and R-6 were paired at 52 percent.

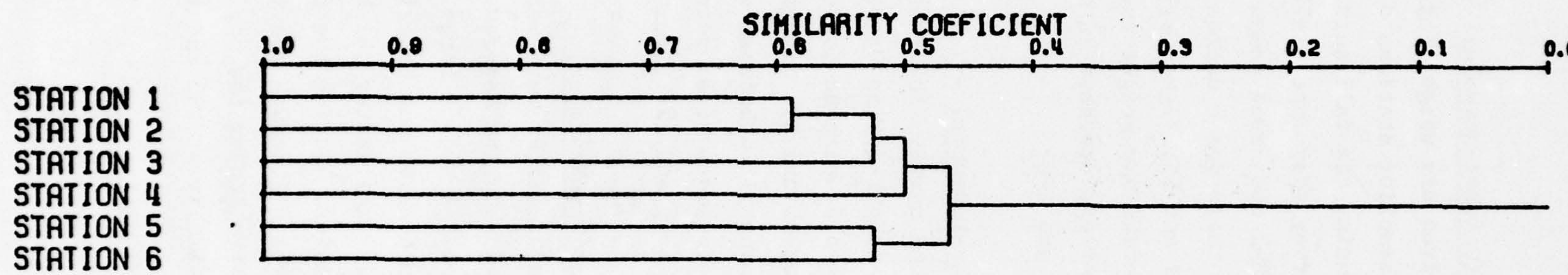
Table 16a. COEFFICIENT OF SIMILARITY COMPARING DIATOM SPECIES ASSOCIATIONS BASED ON COMBINED SPECIES DATA, NATURAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER, 1975

| Station | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | |
| 2 | 0.588 | 1.000 | | | | |
| 3 | 0.501 | 0.549 | 1.000 | | | |
| 4 | 0.492 | 0.487 | 0.511 | 1.000 | | |
| 5 | 0.517 | 0.457 | 0.436 | 0.483 | 1.000 | |
| 6 | 0.470 | 0.507 | 0.454 | 0.445 | 0.524 | 1.000 |

In summary there were 10 diatom species which were common (five to 30 percent occurrence) on natural substrates at six stations. Only one of these, *Navicula gregaria* Donk var. *gregaria* was common to all stations. The remaining species occurred at various levels between the six stations, sometimes being absent or only rare and uncommon. Similar to diatom species occurrence on artificial substrates during November, there was never a drastic shift in species dominance of diatoms on natural substrates. Also the common or very common species comprised a lower percentage of the total diatom community on natural substrates than seen on artificial substrates. Differences of diatom communities on natural substrates were insignificant between stations and were the result of the occurrence, loss, and recurrence of uncommon and rare species. No single species or species group showed significant variations in occurrence and distribution on natural substrates during November 1975.

Figure 40.

RAAP PERIPHYTON-STATION COMPARISON OF NATURAL SUBSTRATES (NOV 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT



Ash-Free Dry Weight (October-November) -

A comparison of ash-free dry weight ($mg/m^2$ and $mg/m^2/day$) showed marked shifts between four sampling stations during October and November, 1975. The observed trend during the fall survey was similar to that observed during the spring survey (May-June, 1975). However, due to the loss of samplers at station R-2 the trend comparison is not completed. Between stations R-1 and R-3 there was a decrease of 42 percent in mean ash-free dry weight (Tables 52 and 53; Figure 41). There was then a two-fold increase in mean ash-free dry weight ($mg/m^2$ and $mg/m^2/day$) between stations R-3 and R-4. A 68 percent decrease in mean ash-free dry weight occurred between stations R-4 and R-6.

Chlorophyll a (October-November) -

Similar to the May-June survey, the trend of chlorphyll a was identical to that of ash-free dry weight during October-November, 1975. Between stations R-1 and R-3 there was a 61 percent decrease in mean chlorophyll a ($mg/m^2$ and $mg/m^2/day$) (Tables 54 and 55; Figure 42). There was then a five-fold increase in mean chlorophyll a between stations R-3 and R-4. Following this increase there was a decrease of 85 percent in mean chlorophyll a ($mg/m^2$ and $mg/m^2/day$) (Tables 54 and 55; Figure 42).

Autotrophic Index (October-November) -

Levels of the autotrophic index were much greater during the October-November survey than during the May-June survey. A value of 210 was calculated for station R-1 with a large increase to 313 at station R-3 (Table 56). The lowest value was calculated at station R-4 (122) which was different from the May-June survey which showed station R-4 to have the highest autotrophic index. During the fall survey station R-6 had a high value at 255 (Table 56). Although the trend of the fall survey was different than that seen during the spring survey, the values determined at station R-4 were similar at 135 and 122 during May-June and October-November respectively.

Table 52. PERIPHYTON ASH- FREE DRY WEIGHT (mg/m$^2$).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA
OCTOBER - NOVEMBER 1975

| Slide position in artificial substrate sampler | Station 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Slide 2 | 734.16 | NS* | 177.21 | 987.32 | NS | NS |
| Slide 5 | 1139.22 | NS | 556.95 | 784.79 | NS | NS |
| Slide 8 | 1999.96 | NS | 987.32 | 1468.33 | NS | NS |
| Slide 11 | 303.79 | NS | 607.58 | 1468.33 | NS | 202.53 |
| Slide 14 | 1037.96 | NS | 708.85 | 1417.69 | NS | 582.27 |
| Slide 9 | NS | NS | NS | NS | NS | 405.06 |
| number of days | 48 | | 48 | 48 | | 48 |
| $\bar{x}$ | 1043.01 | NS | 607.58 | 1225.29 | NS | 396.62 |
| $s^2$ | 313,373.94 | NS | 68447.96 | 81164.92 | NS | 24069.36 |
| s | 559.80 | NS | 261.62 | 284.89 | NS | 155.14 |

*No sample

Table 53 PERIPHYTON ASH-FREE DRY WEIGHT (mg/$m^2$/day )
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA.
OCTOBER - NOVEMBER 1975

| Slide position in *artificial substrate* sampler | | | *Station* | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Slide 2 | 15.29 | NS* | 3.69 | 20.57 | NS | NS |
| Slide 5 | 23.73 | NS | 11.60 | 16.34 | NS | NS |
| Slide 8 | 41.66 | NS | 20.56 | 30.59 | NS | NS |
| Slide 11 | 6.33 | NS | 12.66 | 30.59 | NS | 4.21 |
| Slide 14 | 21.62 | NS | 14.76 | 29.53 | NS | 12.13 |
| Slide 9 | NS | NS | NS | NS | NS | 8.44 |
| number of days | 48 | | 48 | 48 | | 48 |
| $\bar{x}$ | 21.73 | NS | 12.65 | 25.52 | NS | 8.26 |
| $s^2$ | 135.97 | NS | 29.68 | 35.25 | NS | 10.47 |
| s | 11.66 | NS | 5.44 | 5.94 | NS | 3.23 |

*No sample

FIGURE 41 Periphyton Ash-Free Dry Weight ($mg/m^2/day$) from Five Replicate Artificial Substratrates. Radford Army Ammunition Plant, New River, Virginia. October-November 1975

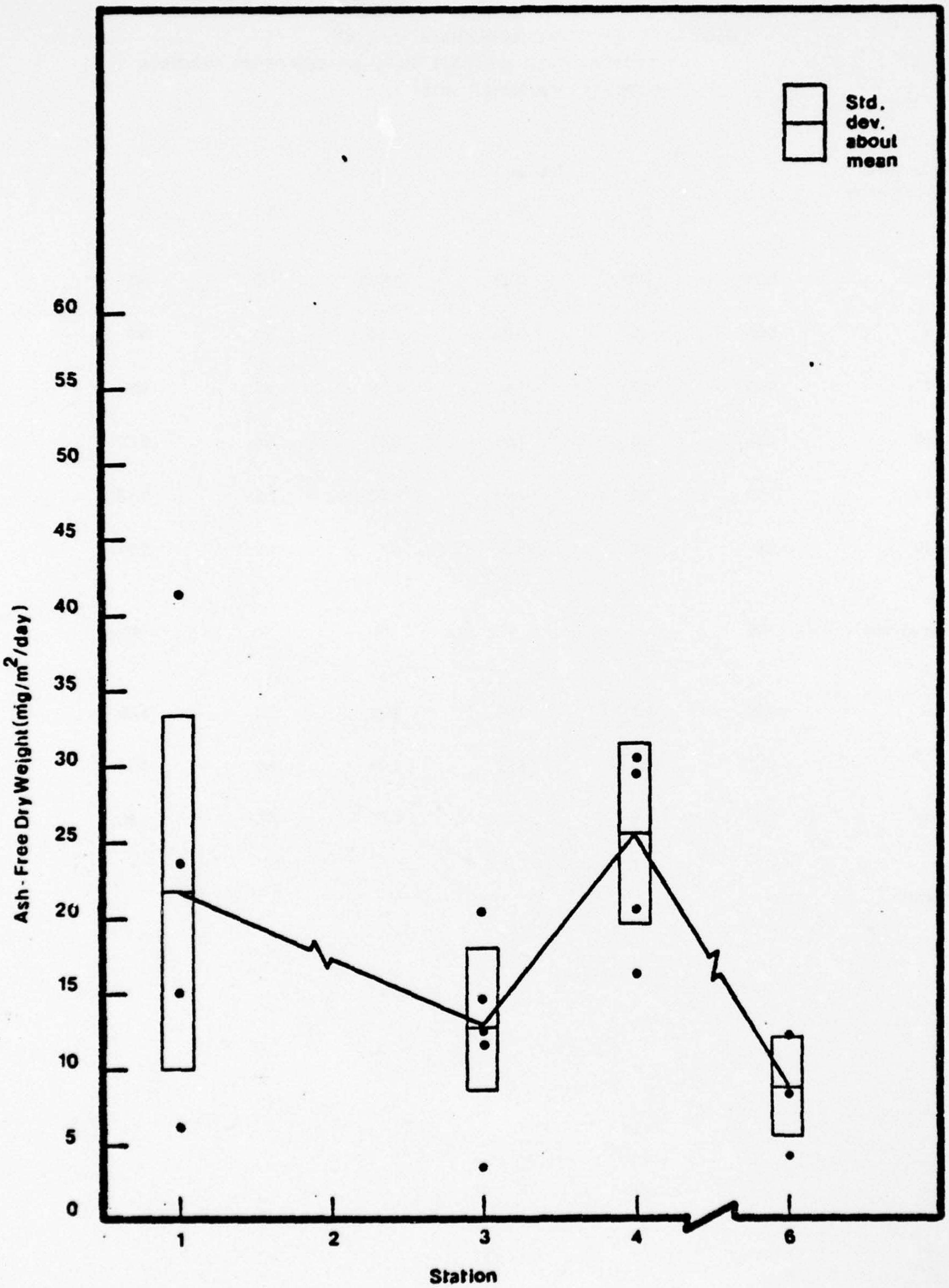


Table 54. PERIPHYTON CHLOROPHYLL a (mg/$m^2$).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA.
OCTOBER - NOVEMBER 1975

| Slide position in artificial substrate sampler | Station | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Slide 1 | 5.71 | NS* | 0.68 | 14.38 | NS | NS |
| Slide 4 | 5.69 | NS | 0.94 | 9.18 | NS | NS |
| Slide 7 | 10.97 | NS | 2.40 | 6.79 | NS | NS |
| Slide 10 | 1.16 | NS | 1.21 | 9.67 | NS | 0.28 |
| Slide 13 | 1.23 | NS | 4.49 | 9.89 | NS | 2.18 |
| Slide 16 | NS | NS | NS | NS | NS | 2.21 |
| number of days | 48 | | 48 | 48 | | 48 |
| $\bar{x}$ | 4.95 | NS | 1.94 | 9.98 | NS | 1.55 |
| $s^2$ | 13.11 | NS | 1.98 | 6.04 | NS | 0.82 |
| s | 3.62 | NS | 1.40 | 2.46 | NS | 0.90 |

*No sample

Table 55. PERIPHYTON CHLOROPHYLL a (mg/m$^2$/day).
RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA
OCTOBER - NOVEMBER 1975

| Slide position in artificial substrate sampler | Station 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Slide 1 | 0.12 | NS | 0.01 | 0.30 | NS* | NS |
| Slide 4 | 0.12 | NS | 0.02 | 0.19 | NS | NS |
| Slide 7 | 0.23 | NS | 0.05 | 0.14 | NS | NS |
| Slide 10 | 0.02 | NS | 0.02 | 0.20 | NS | 0.01 |
| Slide 13 | 0.02 | NS | 0.09 | 0.20 | NS | 0.04 |
| Slide 16 | NS | NS | NS | NS | NS | 0.04 |
| Number of days | 48 | | 48 | 48 | | 48 |
| $\bar{x}$ | 0.1032 | NS | 0.0404 | 0.2079 | NS | 0.0323 |
| $s^2$ | 0.0055 | NS | 0.0085 | 0.0025 | NS | 0.0003 |
| $s$ | 0.0754 | NS | 0.0922 | .0513 | NS | 0.0187 |

* No sample

FIGURE 42 Periphyton Chlorophyll a (mg/m$^2$/day) from Five Replicate Artificial Substrates. Radford Army Ammunition Plant, New River, Virginia.

October—November 1975

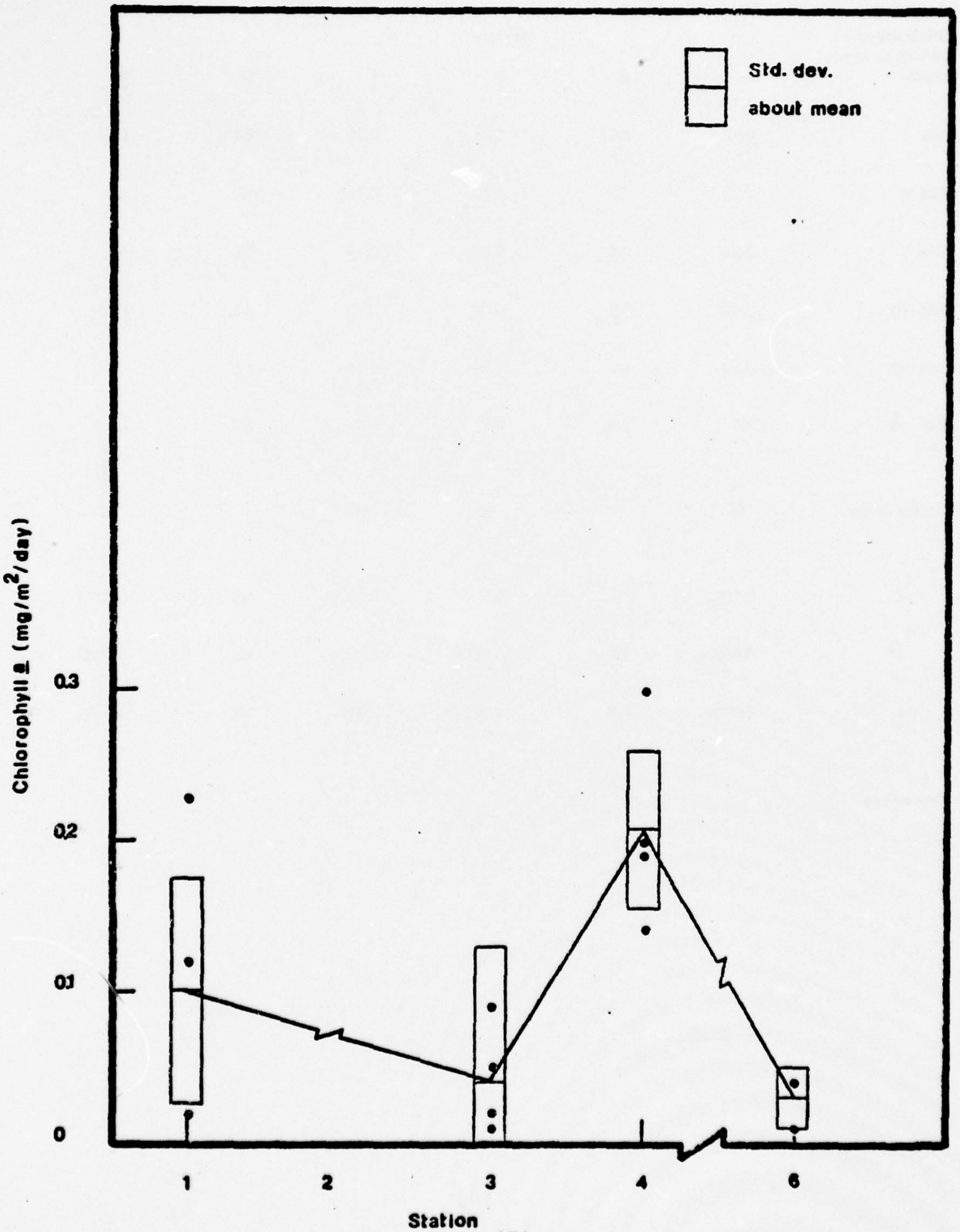


Table 56. PERIPHYTON AUTOTROPHIC INDEX. RADFORD ARMY AMMUNITION PLANT, RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER, 1975

| | Station | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Autotrophic Index* | 210.71 | NS** | 313.18 | 122.77 | NS | 255.88 |

*Autotrophic Index was calculated from the means of five values ash-free dry weight ($mg/m^2$) and five values chlorophyll a ($mg/m^2$) from each station.

**No sample

Table 57. PERIPHYTON CHLOROPHYLL BEFORE ACIDIFICATION:AFTER ACIDIFICATION RATIO, RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER, 1975[1]

| Slide position in artificial substrate sampler | Station 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Slide 1 | 1.61 | NS* | 1.24 | 1.68 | NS | NS |
| Slide 4 | 1.60 | NS | 1.94 | 1.76 | NS | NS |
| Slide 7 | 1.73 | NS | 1.42 | 1.72 | NS | NS |
| Slide 10 | 1.39 | NS | 1.45 | 1.67 | NS | 0.86 |
| Slide 13 | 1.53 | NS | .181 | 1.64 | NS | 1.79 |
| Slide 16 | NS | NS | NS | NS | NS | 1.63 |
| x | 1.57 | NS | 1.57 | 1.69 | NS | 1.43 |
| $s^2$ | 0.01 | NS | 0.06 | 0.001 | NS | 1.65 |
| s | 0.11 | NS | 0.24 | 0.04 | NS | 0.40 |

[1]Ratios of 1.7 are considered free of pheophytin and a ratio of 1.0 indicates pheophytin in the absence of chlorophyll.

*No sample

The algal portion of the periphyton communities collected from artificial substrates was considered to be living and viable. This was determined through the use of the periphyton chlorophyll before:after acidification ratio. At all stations the mean ratio was not less than 1.4. Stations R-1 and R-3 had before:after acidification ratios of 1.57, station R-4 had a ratio of 1.69, and the lowest level was found at station R-6 (1.43) (Table 57). The absence of pheophytin suggest the viability of the algal portion of the periphyton community giving reliability to the autotrophic index.

Discussion of Results (October-November, 1975)

Species Occurrence -

Diatom dominance on artificial substrates (October-November) - Observed trends of diatom species diversity during the fall, 1975, were not as significant as, nor did they parallel, the trends observed during the spring survey. Diversity was quite similar at stations R-1, R-3, and R-6. Contrary to the spring survey diversity decreased at station R-4. The decrease in diatom species diversity was associated with slight increases in nitrite-N, nitrate-N, ammonia-N, total Kjeldahl-N, total phosphorus, chromium,and nitroglycerin. Although there were increases in the above mentioned water chemistry parameters at station R-4, this does not appear to be sufficient to cause a shift in species diversity. The diversity decrease may be the result of these and other parameters in combination. Overall, diversity was low on artificial substrates during October-November.

Similarity of diatom species associations was high, particularly when adjacent stations were compared. It has been shown that proximal stations will support very similar species associations if not influenced by changing physico-chemical factors[26]. In the study area adjacent station pairs R-1/ R-3 and R-3 / R-4 were similar. There are two waste outfalls between stations R-1 and R-3, and the high similarity (71 percent) of diatom

associations between these stations suggests little or no effect of these wastes on diatom species. In a like manner there was an outfall between stations R-3 and R-4, plus the combined affects of two outfalls upstream from station R-3, and there was high similarity (83 percent) between diatom associations at these stations. This further suggests little affect of the wastes discharged.

The fact that station pairs R-1 and R-4 had the lowest similarity (65 percent) indicates that small affects on diatom species associations may occur from waste outfalls 18, 19, and 20. These wastes include wash from the spent acid storage and nitrater area, and nitroglycerin transport wash water containing acetone and soda ash. Observed affects are minimal and apparently involved only the uncommon and rare diatom species. Species dominance of diatoms on artificial substrates was not altered by the waste materials.

Species occurrence was dominated at all stations by Cocconeis placentula var. euglypta (Ehr.) Cl. and C. placentula var. lineata (Ehr.) V.H. These species are characteristic to artificial substrates under the conditions found in the New River. This association accounted for 71 to 96 percent of the species complexes at the four stations sampled during November. They are typically epiphytic or periphytic occurring in circumneutral to alkaline waters, pH (4.7) - 6.2 - 9.0, and are apparently "indifferent" to salt[32,41]. Other species of diatom associations which were common or occasional were Achnanthes minutissima Kuetz. var. minutissima and A. linearis var. pusilla Grun. The former occurs under a wide range of pH (4.3 - 9.2), optimal conditions being 6.5 - 9.0, and is oligohalobic or "indifferent" to salt[32,41]. The latter is typical of fast-flowing, circumneutral streams of Pennsylvania[32]. These are conditions characteristic of the New River in the area of the RAAP.

Diatom dominance on natural substrates (October-November) - The trend of diatom species diversity on natural substrates during October-November was similar to the trends observed during May-June from both artificial and natural substrates. The trend differed from that seen on artificial substrates during the fall survey in that an opposite trend was seen at station R-4. Similar to the May-June survey diversity was two to three times greater on natural than on artificial substrates. No adverse affect of the wastes was evident as diatom species diversity on natural substrates was high and showed almost no variance.

As shown previously, diatom associations were most similar between adjacent station pairs indicating little influence of the waste discharges. Contrary to the trends seen on artificial substrates the level of similarity was somewhat lower although diversity was higher. Other station combinations had lower similarities although the difference was not great.

Common and dominant species occurring on natural substrates were of an *Achnanthes*/*Navicula*/*Nitzschia* complex. Most significant of these was *Navicula gregaria* Donk. var. *gregaria* which commonly occurred at all stations and is characteristic of brackish to fresh waters of high mineral content. Other common species of *Navicula* included: *N. cincta* (Ehr.) Ralfs var. *cincta* - usually found in slightly brackish to slightly alkaline or hard water; *N. minima* Grun. var. *minima* - an alkaliphilous toxon occurring within the pH range of 6.2 - 9.0 (optimum 7.5 - 8.0), it is salt "indifferent" and is often associated with eutrophic conditions; *N. mutica* var. *undulata* (Hilse) Grun. - brackish to hard waters rich in nutrient salts; and *N. radiosa* var. *tenella* (Breb. *ex* Kuetz.) Grun. - waters of low mineral content[32,41].

The Nitzschia portion of the common association was composed of: N. palea (Kuetz.) W. Sm. var. palea - pH indifferent (4.2 - 9.0) with optimum growth at pH 8.4, eutrophic, salt "indifferent" ; N. clausii Hantzsch var. clausii - alkaliphil to pH indifferent (6.8 - 8.2) with optimum growth in the upper range; and N. parvula Lewis var. parvula - pH indifferent (6.6 - 7.9) and salt "indifferent"[32,41].

Similar to the complex found on artificial substrates Achnanthes linearis var. pusilla Grun. and A. minutissima Kuetz. var. minutissima were common to natural substrates. The former is characteristic of fast-flowing, circumneutral streams and the latter is oligohalobic to salt indifferent tolerating a pH range of 6.5 - 9.0.

Conditions within the study area of the New River are within the ranges of the autecology of the common, dominant diatom species which were tabulated. At no point was there an occurrence or loss of a common taxon due to water chemistry conditions changing in favor of or against its survival. Possible affects of munitions wastes on periphyton species associations were minimal if existent and at no time influenced the common or dominant taxa. Species variations were undoubtedly caused by a combination of natural physical factors and waste discharge. No effects were long term as species diversity recovered quickly.

Although there appears to be affects of wastes on diatom species diversity on artificial substrates this may not reflect the real conditions. Since the species association occurring on natural substrates is more complex, i.e., diverse, and the dominant species occur at a lower percentage, the affects of the industrial wastes are not as evident as reflected by artificial substrate comparisons. The species association occurring on artificial substrates is less complex and the dominant species occurred at a higher frequency therefore physico-chemical factors causing minor changes in the species association had greater impact on diversity and similarity comparisons. Thus, affects seen

on artificial substrates may be somewhat more obvious or exaggerated, however, it was shown that these affects were short-term and that recovery occurred within the study area.

Ash-Free Dry Weight (October-November) -
The trend of ash-free dry weight during October-November was identical to that observed during the spring survey. Values were not, however, as great during the fall survey, but the observed variations were still significant (Table 58 ). Conditions appeared to be somewhat inhibitory in the area of stations R-3 and R-6 and stimulatory at station R-4.

Table 58 ANALYSIS OF VARIANCE OF ASH-FREE DRY WEIGHT ($mg/m^2/day$).

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 17 | 1815.90 | | |
| Treatment (between) | 3 | 779.96 | 259.99 | 3.51* |
| Error (within) | 14 | 1035.93 | 74.00 | |

F (0.95) = 3.34

*significant variation

Chlorophyll a (October-November) -

Similar trends were seen between the two surveys with chlorophyll a production ($mg/m^2/day$) being within the same range. Affects appeared inhibitory at stations R-3 and R-6 and stimulatory at station R-4. These variations were significant at the 95 percent level of confidence (Table 59).

Table 59. ANALYSIS OF VARIANCE OF CHLOROPHYLL a ($mg/m^2/day$)

| Source | df | SS | MS | F |
|---|---|---|---|---|
| Total | 17 | 0.14 | | |
| Treatment (between) | 3 | 0.09 | 0.03 | 8.60* |
| Error (within) | 14 | 0.05 | 0 | |

F (0.95) = 3.34
*significant variation

Autotrophic Index (October-November) -

Conditions of the periphyton during the fall survey were quite heterotrophic, all values being over 100. As shown previously this index varies as a function of ash-free dry weight and/or chlorophyll. The results of the high (>100) autotrophic index values are in response to increases and/or disproportionate decreases in ash-free dry weight rather than decreases in chlorophyll a values. Mean chlorophyll values were more constant between stations than were ash-free dry weights.

Variations in periphyton ash-free dry weight and chlorophyll do not correspond well with conditions of water chemistry. It was shown that during October there was an increase in total Kjeldahl nitrogen, nitrate nitrogen, and TOC between station R-1 and R-4. This may partially

explain the "stimulatory" affect on periphyton growth at station R-4 but does not explain the decreases which are observed at station R-3 and R-6. TOC continues to increase through station R-6 although nitrate-nitrogen begins to decrease. The increase in chromium may be partly responsible for biomass decreases at station R-6 during both surveys but there is no positive correlation.

Since outfall number 18 was characterized by high levels of nitrogen compounds, total Kjeldahl nitrogen, and COD it may be the stimulatory cause observed at station R-4. As indicated in the station descriptions, due to river flow conditions station R-3 would probably not receive the full impact of wastes from outfalls 18 and 19. However, the location of station R-4 was such to receive the wastes from outfalls 18, 19, and 20. This would then explain the stimulatory affect on periphyton at station R-4 which is obviously only a short term affect. Apparently waste discharges from sources upstream and opposite of the Nitroglycerin No. 2 area may exert an affect on the periphyton in the area studied.

In general it can be stated that potential affects of nitroglycerin munition waste compounds on periphyton are not adverse and are very localized. Species associations vary but recover within the study area. Affects on primary production as reflected by chlorophyll a are also localized and appear to be insignificant when the New River is considered in its total.

BENTHIC MACROINVERTEBRATES

## Analytical Procedures

Preserved/stained samples were returned to the laboratory where they were again screened and washed in a fine mesh sieve (No. 40, U.S. Standard sieve). These samples were then picked and sorted in white enamel trays. A binocular dissecting microscope was used to identify all specimens and to sort specimens of the Family Chironomidae into generic groups and subgroups. Head capsule slide mounts of the Chironomidae were made and specimens were identified to the generic level using a compound microscope at 100 X and 400 X magnification. CMC - 10 or polyvinyl lactophenol mounting media was used for slide preparation. Identifications were in accordance with the taxonomic keys listed in Appendix XII. Samples collected from the natural substrates (kick method) and artificial substrates (rock baskets) were processed and analyzed in a similar manner. Species lists detailing distribution were prepared and are included as appendices. Data was expressed as number of organisms per kick sample or as numbers per basket sampler.

Species diversity and evenness were determined for all replicate samples and plotted against station location. Mean species diversity and standard deviation of the replicate samples were calculated for trend analysis. Coefficient of similarity was used to compare replicate natural and replicate artificial substrate samples.

Species data from replicate samples at each station were combined and compared to all other stations using the coefficient of similarity. Comparisons were also drawn between species occurrence from natural substrates and from artificial substrates at each station.

For the comparison of replicate and station similarity of benthic macroinvertebrates species data from artificial substrates, formula "B"

of the Pinkham and Pearson Coefficient of Association was utilized. Mutual absence of species, i.e., 0/0 matches were scored as one[35,36]. This formula is used for samples collected from the same technique and when there are differences in density values between samples.

Species data taken from natural substrates were compared using the "B" formula and 0/0 matches scored as one. This formula is used when sampling methods between samples are not the same[35,36].

Results,(May-June, 1975)

Species Occurrence on Artificial Substrates (May-June) - Variations in species occurrence of benthic macroinvertebrates collected from artificial substrate samplers, i.e., rock baskets, were not great. Species diversity and population similarity were somewhat consistent between stations with little variation.

Species diversity of replicate samples and the mean and standard deviation of these samples are presented in Table 60 and plotted in graphic form in Figure 43. Species evenness is given in Table 61. From these data it is observed that species diversity and evenness were quite similar between replicates within any station. Most often four of the five replicates were nearly identical in terms of species diversity, with the fifth replicate being higher or lower, and falling outside of the standard deviation (Table 60 and Figure 43).

The following trends were observed:

1. There was a slight decrease in mean species diversity and evenness between station R-1 (2.41), the reference station, and stations R-2 and R-3, mean diversity of 2.05 and 2.08 respectively (Figure 43). From Appendix XIII it is seen that this is the result of a shift in the number of taxa as the total number of individuals remained constant.

Table 60 SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FIVE REPLICATE ROCK BASKET SAMPLERS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE 1975

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 2.37 | 2.18 | 2.16 | 2.24 | NS* | 2.12 |
| 2 | 2.59 | 2.15 | 1.74 | 2.21 | NS | 2.31 |
| 3 | 2.00 | 2.07 | 2.13 | 2.18 | NS | 2.51 |
| 4 | 2.40 | 2.07 | 2.13 | 2.24 | NS | 2.40 |
| 5 | 2.68 | 1.76 | 2.23 | 2.27 | NS | 2.40 |
| $\bar{x}$ | 2.41 | 2.05 | 2.08 | 2.23 | NS | 2.35 |
| $s^2$ | .069 | .028 | .037 | .0012 | NS | .021 |
| $s$ | 0.26 | 0.17 | 0.19 | .034 | NS | 0.15 |

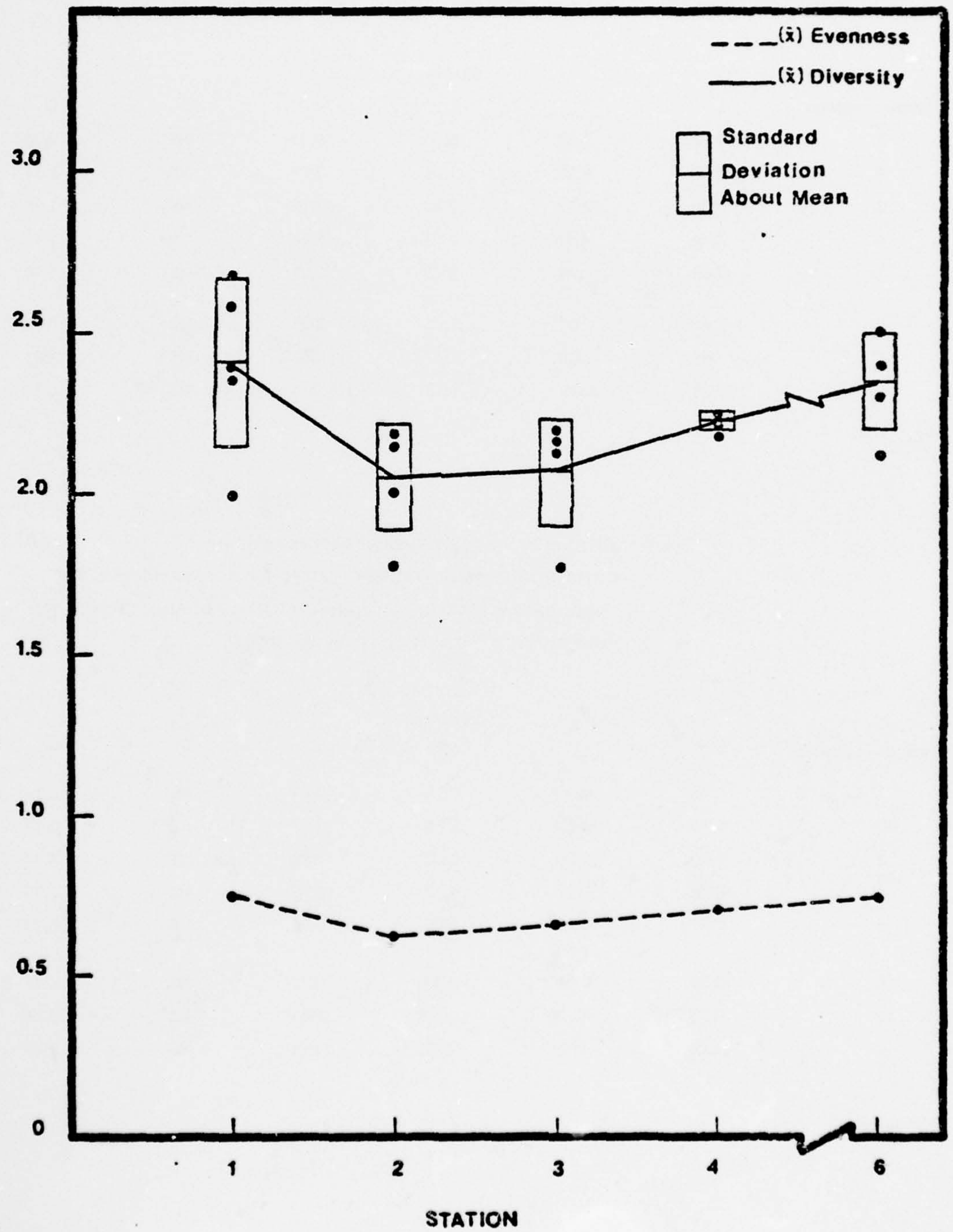
*No sample

Table 61. SHANNON- WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FIVE REPLICATE ROCK BASKET SAMPLERS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE 1975.

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0.76 | 0.69 | 0.75 | 0.71 | NS* | 0.71 |
| 2 | 0.78 | 0.66 | 0.61 | 0.67 | NS | 0.73 |
| 3 | 0.59 | 0.69 | 0.65 | 0.70 | NS | 0.75 |
| 4 | 0.69 | 0.61 | 0.65 | 0.70 | NS | 0.75 |
| 5 | 0.81 | 0.57 | 0.69 | 0.76 | NS | 0.75 |
| $\bar{x}$ | 0.73 | 0.64 | 0.67 | 0.71 | NS | .74 |
| $s^2$ | 0.008 | .0028 | .0028 | .0010 | NS | .0003 |
| $s$ | .088 | .053 | .053 | .033 | NS | .018 |

*No sample

FIGURE 43. Shannon—Weaver Species Diversity and Evenness of Benthic Macroinvertebrates Collected from Five Replicate Artificial Substrates (Rock Basket Samplers).
Radford Army Ammunition Plant, New River, Virginia.
May—June 1975



2. Species diversity and evenness remained the same at stations R-2 and R-3, and increased slightly at station R-4 to a level of 2.23. This shift is the result of a decrease in the total number of organisms as number of taxa remained constant at 23 (Appendix XIII).
3. Mean species diversity at station R-6, the recovery station, approached the level seen at the reference station 1 (Figure 43). Mean diversity was 2.35 at station R-6; up from 2.23 at station R-4 (Table 60). Due to river conditions the samplers at station R-5 were not recovered therefore there is no comparative data for this location.

Mean species diversity is relatively high and does not change significantly between stations.

The coefficient of similarity was applied to the replicate samples at each station in an effort to determine the degree of population variation within each station. At station R-1 replication was at the 50 percent level. Four replicates were similar at 48-50 percent with the fifth sample being similar to the other four at a level of about 39 percent (Figure 44). The most different replicate is also revealed in the species diversity data.

Species similarity between replicates was more variable at station R-2 (Figure 45). Two replicates were similar at the 61 percent level while a third sample was similar to this pair at the 59 percent level. The remaining two replicates were similar to the first three at about 48 and 41 percent. This was not necessarily shown by the diversity comparisons.

Sample replication at station R-3 was quite variable (Figure 46). One pair of replicates was similar at the 65 percent level and a second pair was similar at the 54 percent level. These two sample pairs, along with the fifth replicate, were similar to each other at about 40 percent.

Figure 44.

STATION R1 - RADFORD BENTHOS - COMPARISON OF ART. SUB. BASKET REP. (MAY-
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION.
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

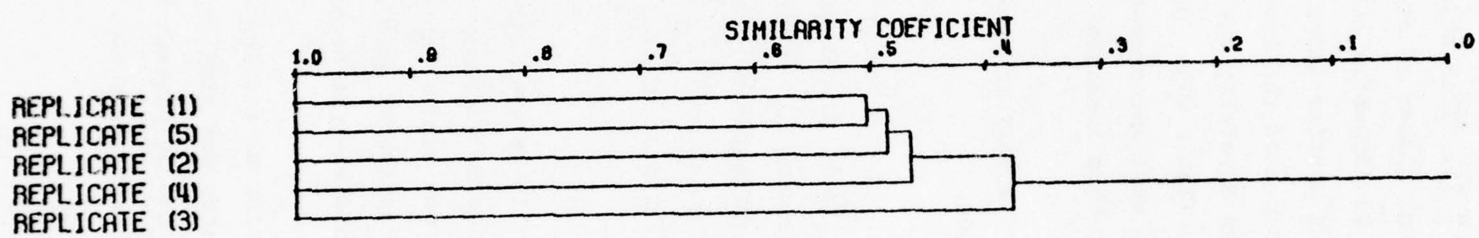


Figure 45.

STATION R2 - RADFORD BENTHOS - COMPARISON OF ART. SUB. BASKET REP. (MAY-

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION.

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

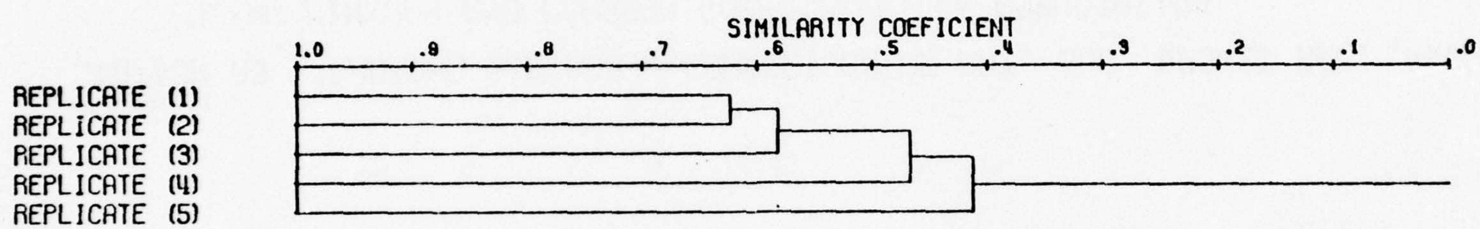
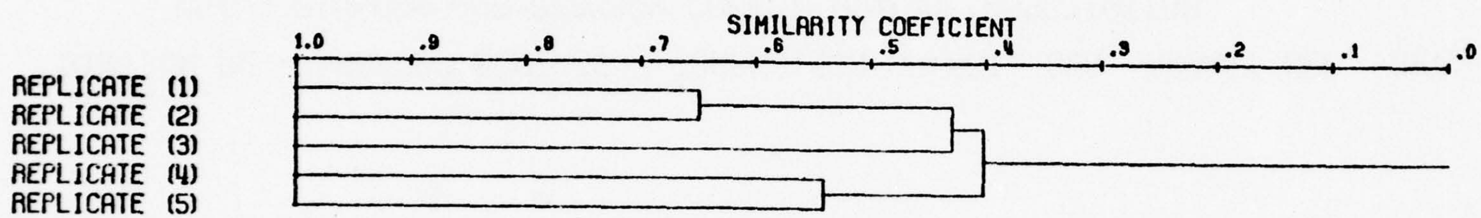


Figure 46.
STATION R3 - RADFORD BENTHOS - COMPARISON OF ART. SUB. BASKET REP. (MAY-
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT



A similar trend was seen at station R-4. One pair of samples was similar at 59 percent, while a second pair at about 55 percent (Figure 47). Both pairs, along with the fifth sample, were similar at a low level of 39 percent.

Similarity at station R-6 was like that at stations R-1 and R-2. One sample pair was similar at the 70 percent level with subsequent samples being similar at 51, 45, and 40 percent (Figure 48). At the reference and recovery stations R-6 and R-1 / R-2 respectively, replicate samples did not group in oppossing pairs. In the areas receiving known industrial wastes, stations R-3 and R-4, two pairs of samples were very similar within themselves, yet very different from each other. The fifth replicate usually had a similarity somewhere between these pairs.

To provide maximum comparison between the benthic macroinvertebrate populations, the replicate samples were combined at each station. These combined species data were then used in a station-to-station comparison using the Pinkham and Pearson coefficient of association. These comparisons are shown in Table 62 and Figure 49.

Table 62. COEFFICIENT OF ASSOCIATION OF BENTHIC MACROINVERTEBRATES ON ARTIFICIAL SUBSTRATES BETWEEN STATIONS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY-JUNE, 1975.

| Stations | R-1 | R-2 | R-3 | R-4 | R-5 | R-6 |
|---|---|---|---|---|---|---|
| R-1 | 1.000 | | | | | |
| R-2 | 0.463 | 1.000 | | | | |
| R-3 | 0.423 | 0.523 | 1.000 | | | |
| R-4 | 0.453 | 0.497 | 0.535 | 1.000 | | |
| R-5 | NS* | NS | NS | NS | NS | |
| R-6 | 0.448 | 0.508 | 0.463 | 0.453 | NS | 1.000 |

*No samples

Figure 47.

STATION R4 - RADFORD BENTHOS - COMPARISON OF ART. SUB. BASKET REP. (MAY-
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

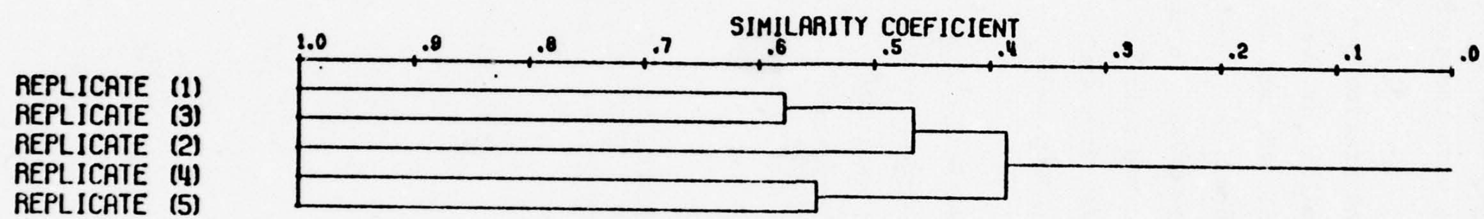


Figure 48.

STATION R6 - RADFORD BENTHOS - COMPARISON OF ART. SUB. BASKET REP. (MAY-
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

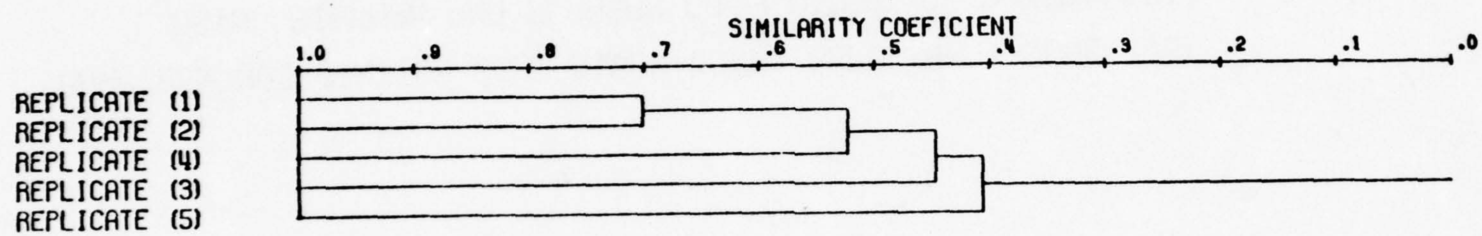


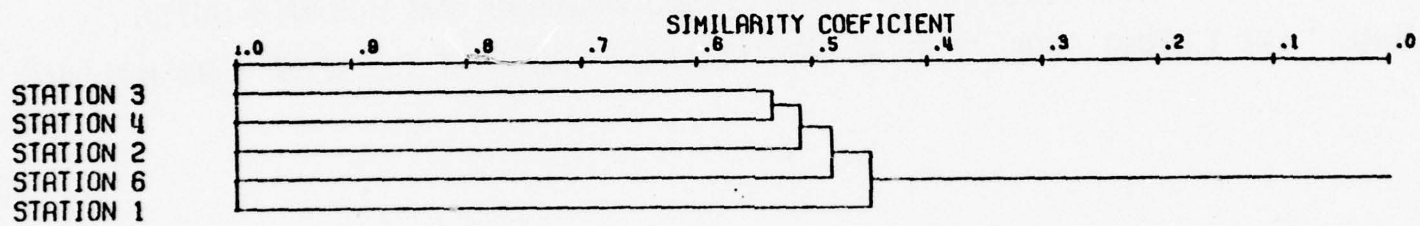
Figure 49.

RAAP BENTHOS STATION COMPARISON-COMB. REPS. (MAY-JUNE '75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



The benthic macroinvertebrate populations were shown to be most similar between stations R-3 and R-4 (53 percent) (Table 62). Stations R-2 and R-3, and R-2 and R-4, were similar at 52 and 50 percent respectively. All stations were similar around the 45 percent level (Figure 49). Of significance here is the pairing of near adjacent stations. Greatest similarity was found between the stations in the area receiving known industrial wastes, i.e., stations R-2, R-3 and R-4. These stations also had greatest variation between replicate samples. However, the benthic populations were not greatly dissimilar between the stations in the study area.

Dominant taxa found on artificial substrates at the five stations of the study area were of a Cheumatopsyche/Isonychia complex. At station R-1 Cheumatopsyche sp. and Isonychia sp.#1 occurred at frequencies of 25 and 17 percent respectively. Also common were Hyalella sp. (15 percent) and Ephemerella deficiens (13 percent) (Appendix XIII). These four taxa comprised 70 percent of the benthic macroinvertebrate population at this station.

Three of the above mentioned taxa repeated as being common at station R-2, and occurred at frequencies nearly equal to their occurrence at station R-1. Cheumatopsyche sp. and Isonychia sp.#1 occurred at 29 and 22 percent respectively (Appendix XIII). Ephemerella deficiens was again common (15 percent), however, Hyalella sp. was replaced by Hydropsyche sp. (12 percent) in the order of occurrence. These four taxa comprised 78 percent of the population at station R-2.

This same association dominated at station R-3, and comprised 72 percent of the total benthic population. Isonychia sp.#1 and Cheumatopsyche sp. were most common, 30 percent and 18 percent respectively. Ephemerella deficiens and Hydropsyche sp. were present at 15 and 9 percent respectively.

Four taxa comprised 67 percent of the benthos population at station R-4. These were the following common taxa: Cheumatopsyche sp. - 25 percent, Ephemerella deficiens - 19 percent, Isonychia sp.#1 - 13 percent, and Stenonema (pulchellum) - 10 percent.

Sixty-five percent of the benthos population at station R-6 was comprised of five taxa. These were: Cheumatopsyche sp. - 25 percent, Ephemerella deficiens - 13 percent, Chironomidae - 10 percent, Isonychia sp.#1 - 8 percent, and Stenonema (pulchellum) - 8 percent.

Of this complex three were common to all stations. The occurrence of all these taxa was at the common level, i.e., 5 - 30 percent occurrence, and underwent no drastic shifts in frequency of occurrence. The common occurrence of these taxa provided a stabilizing factor to the species associations at the stations studied. The variations in species diversity and population similarity of benthic macroinvertebrates on artificial substrates was apparently the result of fluctuations in the occurrence of occassional and rare taxa which added only a small part to the species associations. There were no significant variations in species diversity or frequency of occurrence of common species. No taxon was the overwhelming dominant at any station.

Species Occurrence on Natural Substrates (May-June) -
The trend of species diversity of benthic macroinvertebrates from natural substrates was relatively high and similar to the trend observed on artificial substrates. As seen previously there was usually one of the five replicates which was most different, having a species diversity falling outside of the calculated standard deviation (Table 63 and Figure 50).

Mean species diversity changed slightly between stations R-1 and R-2, increasing from 2.21 to 2.33 (Table 63 and Figure 50 ). Diversity then decreased to 2.28 at station R-3 and increased to 2.34 at station R-4. These are only small variations and are insignificant. The greatest

Table 63. SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FIVE REPLICATE NATURAL SUBSTRATES (KICK METHOD). RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY-JUNE 1975

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 1.90 | 2.34 | 2.06 | 2.44 | NS* | 2.88 |
| 2 | 2.04 | 2.27 | 2.13 | 2.34 | NS | 2.54 |
| 3 | 2.31 | 2.39 | 2.63 | 2.98 | NS | 2.67 |
| 4 | 2.44 | 2.23 | 2.30 | 2.16 | NS | 2.32 |
| 5 | 2.34 | 2.44 | 2.30 | 1.76 | NS | 2.61 |
| $\bar{x}$ | 2.21 | 2.33 | 2.28 | 2.34 | NS | 2.60 |
| $s^2$ | 0.050 | .007 | .049 | 0.197 | NS | .041 |
| s | 0.226 | .086 | .220 | 0.444 | NS | .203 |

* no sample

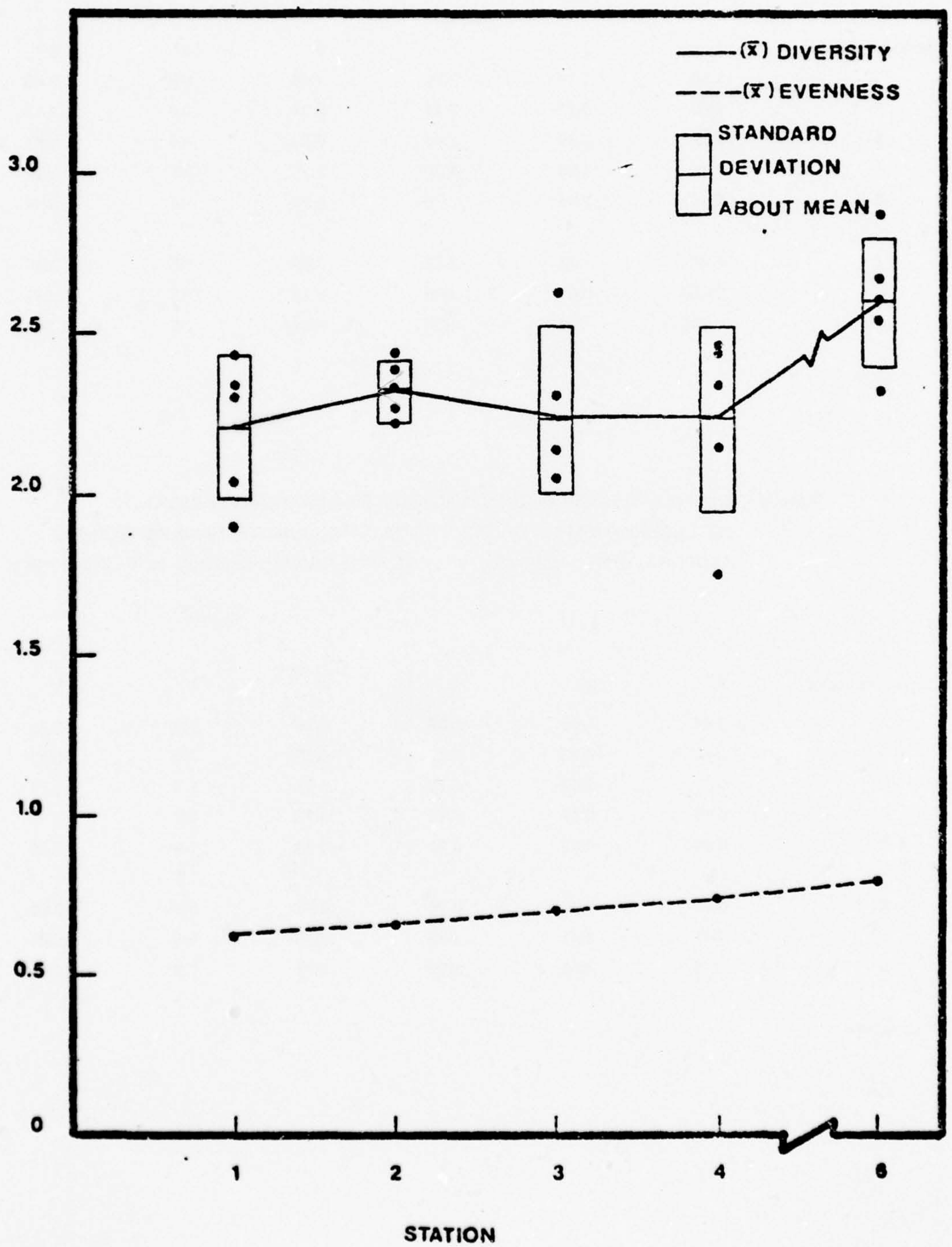
Table 64. SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM FIVE REPLICATE NATURAL SUBSTRATES (KICK METHOD). RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY - JUNE 1975

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0.56 | 0.68 | 0.66 | 0.75 | NS* | 0.83 |
| 2 | 0.62 | 0.62 | 0.62 | 0.77 | NS | 0.81 |
| 3 | 0.61 | 0.67 | 0.77 | 0.78 | NS | 0.77 |
| 4 | 0.66 | 0.67 | 0.70 | 0.76 | NS | 0.79 |
| 5 | 0.64 | 0.72 | 0.73 | 0.60 | NS | 0.80 |
| $\bar{x}$ | 0.62 | 0.67 | 0.70 | 0.73 | NS | 0.80 |
| $s^2$ | .001 | .001 | .003 | .006 | NS | .001 |
| s | .038 | .036 | .059 | .075 | NS | .022 |

* no sample

FIGURE 50. Shannon-Weaver Species Diversity and Evenness of Benthic Macroinvertebrates Collected from Five Replicate Natural Substrates (Kick Method). Radford Army Ammunition Plant, New River, Virginia.

June 1975



change in mean species diversity occurred at station R-6 where diversity increased to 2.60 (Table 63 and Figure 50). Between all stations it was observed that species evenness increased steadily (Table 64 and Figure 50).

Use of the Pinkham and Pearson coefficient of association indicates that sample replicates within each station were similar in species occurrence and structure at about the 50 percent level. At station R-1 there were three replicates which were similar at the 51 percent level. The remaining two samples were similar to the first three samples at 45 and 39 percent respectively (Figure 51).

Two pairs of samples were associated at station R-2. One pair of replicates was similar at the 59 percent level while the second pair was similar at the 51 percent level. These sample pairs were similar to each other and to the fifth replicate at lower levels of 46 and 41 percent respectively (Figure 52).

A similar trend occurred at station R-3 (Figure 53). Two samples paired at the 58 percent level while a second set of samples paired at the 42 percent level. The fifth sample was most similar to the former pair and all samples were similar at the 41 percent level.

Oppossing replicate pairs did not occur at station R-4. All replicates were similar at the 41 percent level (Figure 54). Two replicates were similar at the 60 percent level while the remaining samples were similar to this pair at 54 and 48 percent respectively.

Replication at station R-6 was nearly identical to that seen at station R-4. One pair of samples was similar at the 61 percent level with subsequent replication being at 51, 49, and 45 percent (Figure 55).

These data on replication indicate that samples from the same station were similar to each other at levels between 40 and 60 percent. From previous

Figure 51.

STATION R1-RAAP BENTHOS-COMPARISON OF NAT. SUB. REPS. - KICK METHOD (MAY

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

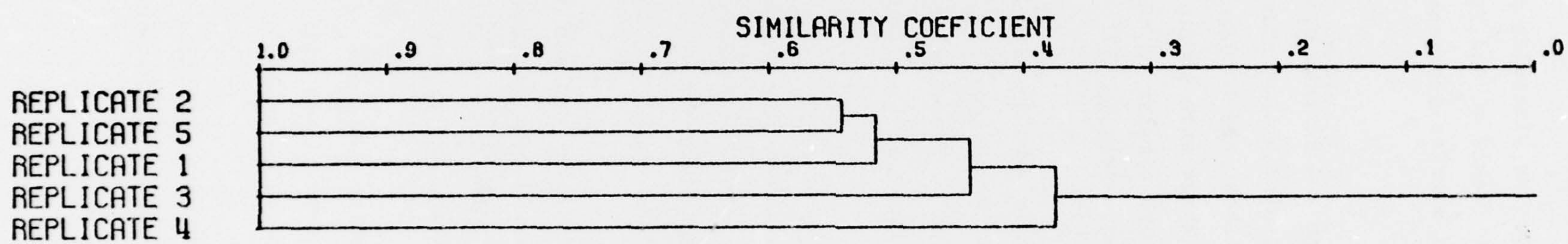


Figure 52.

STATION R2-RAAP BENTHOS-COMPARISON OF NAT. SUB. REPS. - KICK METHOD (MAY

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

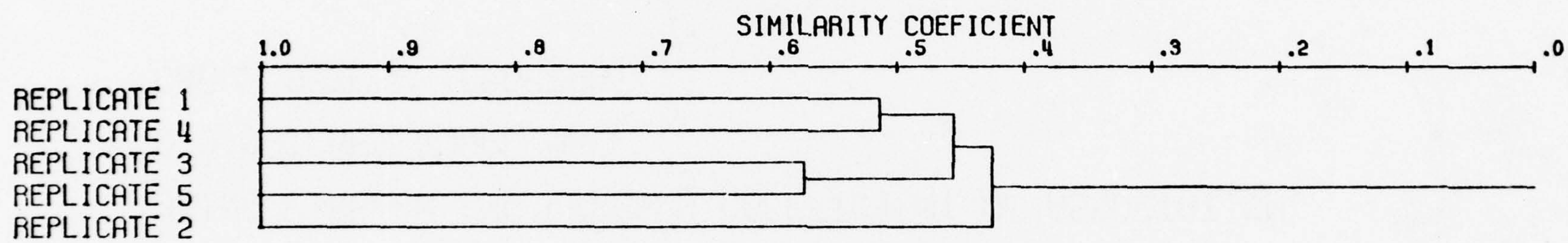


Figure 53.

STATION R3-RAAP BENTHOS-COMPARISON OF NAT. SUB. REPS. - KICK METHOD (MAY

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION.

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

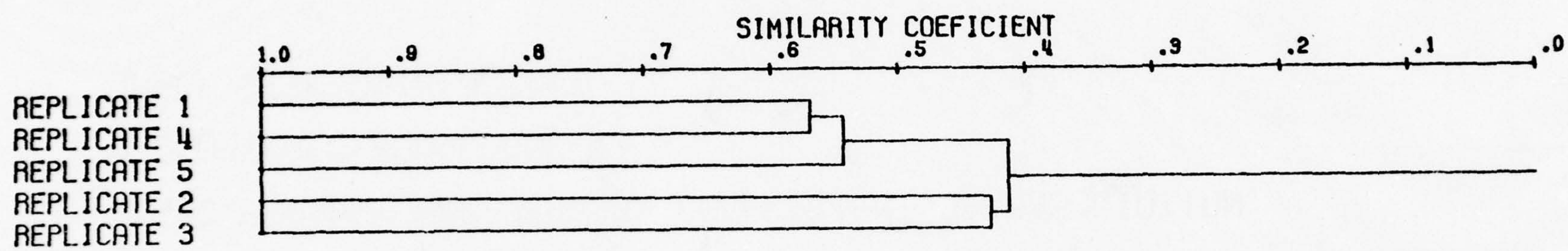


Figure 54.
STATION R4-RAAP BENTHOS-COMPARISON OF NAT. SUB. REPS. - KICK METHOD (MAY
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

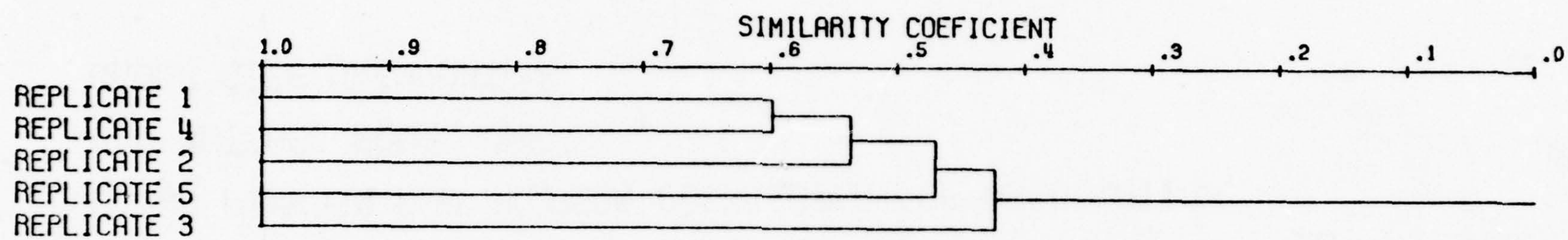
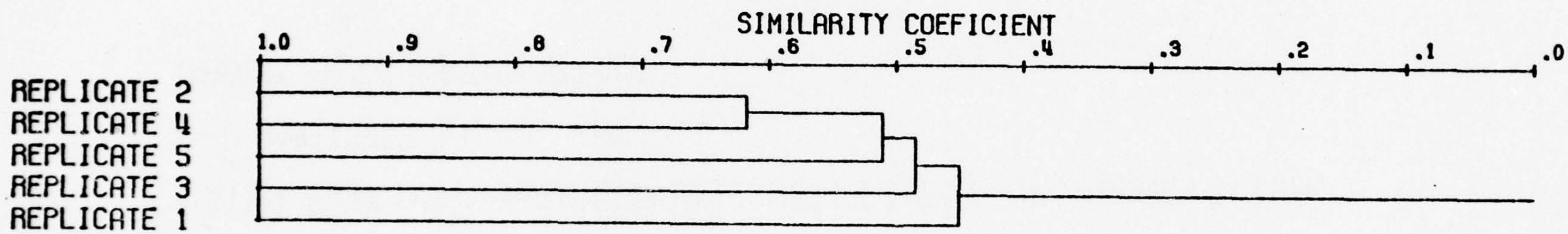


Figure 55.
STATION R6-RAAP BENTHOS-COMPARISON OF NAT. SUB. REPS. - KICK METHOD (MAY
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT



data this seems to be normal. To form a more complete population base for station-to-station comparisons the species data of all replicates at each station were combined. This combined data was then used in the Pinkham and Pearson coefficient of association to determine the degree of population variation between stations.

Table 65. COEFFICIENT OF ASSOCIATION OF BENTHIC MACROINVERTEBRATES ON NATURAL SUBSTRATES BETWEEN STATIONS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. MAY-JUNE, 1975.

| Stations | R-1 | R-2 | R-3 | R-4 | R-5 | R-6 |
|---|---|---|---|---|---|---|
| R-1 | 1.000 | | | | | |
| R-2 | 0.533 | 1.000 | | | | |
| R-3 | 0.436 | 0.516 | 1.000 | | | |
| R-4 | 0.274 | 0.322 | 0.319 | 1.000 | | |
| R-5 | NS* | NS | NS | NS | NS | |
| R-6 | 0.407 | 0.449 | 0.465 | 0.280 | NS | 1.000 |

*No sample

Greatest benthos species similarity on natural substrates was seen between stations R-1, R-2, and R-3. Near adjacent station pairs of stations R-1 / R-2, and R-2 / R-3 were similar at 53 and 52 percent respectively (Table 65). The remaining adjacent station pairs, i.e., R-3 / R-4 and R-4 / R-6, had low similarities of 32 and 28 percent respectively (Table 65). Least similar was station R-1 when compared to station R-4. Figure 56 graphically reflects these trends, showing stations R-1 and R-2 (reference stations) to be very similar. Stations R-3 and R-6 were similar to these two upstream stations at slightly lower levels. Least similar was station R-4, which compared to all other stations at an average of 30 percent (Figure 56).

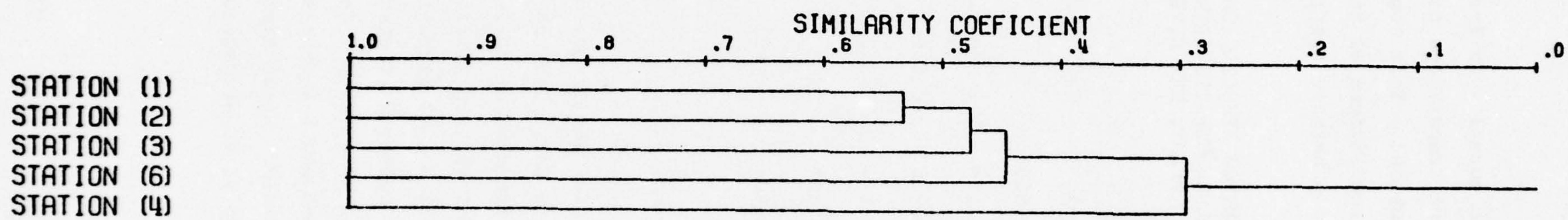
Figure 56.

RAAP BENTHIC MACROINVERTBRATES-NAT. SUB. -COMB. REPLICATES (MAY-JUNE '

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



As shown by the data collected form artificial substrates, greatest variation and difference between benthic macroinvertebrate samples occurred in the area of know industrial waste discharge. However, the dominant species complex on natural substrates at each station was different from that seen on artificial substrates. There were no drastic shifts in the frequency of occurrence of the dominant taxa except at station R-4. This was reflected by coefficient of similarity.

Four taxa comprised 70 percent of the species assoication at station R-1. Most common were Hyalella sp. (26 percent) and Ephemerella needhammi (19 percent) (Appendix XIV). E. deficiens and Lepidostoma sp. occurred at frequencies of 13 and 12 percent respectively.

Sixty-six percent of the benthos population at station R-2 was comprised of four taxa. These were: Ephemerella needhammi - 25 percent, E. deficiens 16 percent, Hyalella sp. - 16 percent, and Hydropsyche sp. - 9 percent.

Occurrence of taxa was similar at station R-3; four taxa formed 66 percent of the total population. The largest shift in occurrence was the increase in Hyalella sp. to 32 percent (up 16 percent) and the decreased frequency of Ephemerella needhammi to 16 percent (down 9 percent). E. deficiens and Stenonema (pulchellum group) occurred at rates of 11 and 7 percent respectively.

The greatest species shifts occurred at station R-4 where three taxa comprised 64 percent of the population. These were: Chironomidae - 28 percent, Stenonema (pulchellum group) - 20 percent, and S. (interpunctatum group) - 16 percent. These taxa were of low occurrence at previous stations (Appendix XIV).

A shift in species occurrence then occurred at station R-6, where four taxa, common to stations R-1, R-2, and R-3, comprised 64 percent of the benthos population. These were: Hyalella sp. - 20 percent, Ephemerella

needhammi and E. deficiens - 13 percent each, and Chironomidae and Pseudocloeon sp. at 9 percent each.

The common taxa of the species complex occurred at all stations except station R-4. Although not shown by species diversity, there was a major shift in the dominant benthic macroinvertebrate taxa at station R-4. This was further substantiated by the coefficient of similarity. The variations in species diversity and population similarity of the benthos was the result of flucuations in the occurrence of occasional, rare, and low common taxa except at station R-4. At this station there was a major shift in the species complex. However, no taxon was an overwhelming dominant at any station.

Discussion of Results (May-June 1975 Survey)

Species diversity of benthic macroinvertebrates on natural and on artificial substrates did not vary greatly. In both cases the middle group of stations, i.e., R-2, R-3, and R-4, had near equal species diversity and differed mostly from the reference station (R-1) and the recovery station (R-6).

Population similarity on artificial substrates was highest between adjacent station pairs in the area of waste discharge. The benthic taxa common to all stations were facultative or intorlerant to organic pollution[37]. The species data gathered from artificial substrate samplers suggest trends in response to population stress in the area of outfalls 18, 19, and 20; stations R-2, R-3, and R-4. These affects were however, minor and there were no drastic shifts in the benthos populations on artificial substrates.

The species complex reported on natural substrates differed from that on artificial substrates. There were minor population shifts on natural substrates with a major shift occurring at station R-4. This shift cannot be directly related to detrimental variations in water or sediment chemistry.

Due to river conditions it was virtually impossible to collect natural substrates close to the artificial substrates and waste outfalls from the Nitroglycerin No.2 area. It is highly possible that variations observed in the benthos populations on natural substrates may be in response to waste discharges from the opposite side of the river.

Changes in benthos population similarity are in association with increases in nitrogen compounds from outfall 18 above station R-2, R-3, and R-4. There was likewise an increase in total organic carbon in this study area but this did not appear to be related to discharges from the Nitroglycerin No. 2 area. Through this area there was also an increase in the level of chromium.

Sediment chemistry reflected increases in chemical oxygen demand, total volatile solids, and total Kjeldahl-nitrogen in moving downstream from station R-1. Total phosphorus and oxidized forms of nitrogen did not change significantly between stations. Chromium in the sediments increased with distance downstream.

Results from the Chemistry section of this report indicate that outfall 18 carries the largest proportion of nitroglycerin wastes from the NG #2 area. It was found that all river stations contained low (negligible) levels of nitroglycerin and no significant variations were related in the area of stations R-2, R-3, and R-4.

The observed variations in benthic macroinvertebrate populations appear to be related in a small degree to waste discharge from the Nitroglycerin No. 2 area. However, these variations are not significant and population recovery appears to occur at station R-6. This is reflected by the high similarity between the reference and recovery stations, R-1 and R-6 respectively. Changes in species associations are likely the result of the combined affects of low levels of industrial wastes and natural variations.

Results, (October-November, 1975)

Species Occurrence on Artificial Substrates (October-November) - After receiving the species data gathered from the May-June survey the decision was made to process, identify, and enumerate three rather than five replicate samples from each station. It was felt that this would not severely limit the reliability of trend analysis.

The level of benthos species diversity on artificial substrates was the same during both surveys although the trend was not identical. Table 66 and Figure 57 present the species diversity, mean, and standard deviation of the sample replicates at each station. From these data it is seen that there was little variation between the diversity of replicate samples. Likewise there was little variation in species evenness (Table 67 and Figure 57).

Mean species diversity increased slightly from station R-1 to station R-2, 2.14 to 2.33 respectively. Mean diversity decreased at station R-3 (2.05)to a level similar to station R-1. Slight increases occurred at stations R-4 and R-6, 2.21 and 2.31 respectively (Figure 57 and Table 66). Mean species evenness was constant between 0.6 and 0.7 (Table 67). Variation in species diversity was minimum and virtually insignificant.

Replication of the three samples at each station was lower than replication of the five replicates analyzed during the earlier survey. It is not certain whether this is a function of season and changing populations or if this is a function of the number of sample replicates. The following was noted:

1. Replication at station R-1 was low at 32 percent with two samples being similar at 38 percent (Figure 58).
2. Overall replicate similarity at station R-2 was likewise about 32 percent although two samples were similar at 44 percent (Figure 59).

Table 66. SHANNON-WEAVER SPECIES DIVERSITY FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATES. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER - NOVEMBER, 1975.

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 2.19 | 2.25 | 1.96 | 2.08 | NS* | 2.32 |
| 2 | 2.17 | 2.39 | 1.97 | 2.31 | NS | 2.33 |
| 3 | 2.04 | 2.36 | 2.21 | 2.24 | NS | 2.28 |
| $\bar{x}$ | 2.14 | 2.33 | 2.05 | 2.21 | NS | 2.31 |
| $s^2$ | 0.006 | 0.005 | 0.020 | 0.014 | NS | 0.001 |
| s | 0.080 | 0.075 | 0.143 | 0.117 | NS | 0.027 |

Table 67. SHANNON-WEAVER EVENNESS FOR BENTHIC MACROINVERTEBRATES COLLECTED FROM THREE REPLICATE ARTIFICIAL SUBSTRATE SAMPLERS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER, 1975.

| | Station | | | | | |
|---|---|---|---|---|---|---|
| Sample replicates | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 0.61 | 0.64 | 0.64 | 0.65 | NS* | 0.67 |
| 2 | 0.64 | 0.73 | 0.60 | 0.66 | NS | 0.70 |
| 3 | 0.58 | 0.69 | 0.66 | 0.61 | NS | 0.61 |
| $\bar{x}$ | 0.61 | 0.69 | 0.63 | 0.64 | NS | 0.66 |
| $s^2$ | 0.001 | 0.002 | 0.001 | 0.001 | NS | 0.002 |
| s | 0.032 | 0.042 | 0.032 | 0.025 | NS | 0.043 |

*No sample

Figure 57 AAAP BENTHOS- DIVERSITY OF ART. SUB. ((OCT-NOV 75)

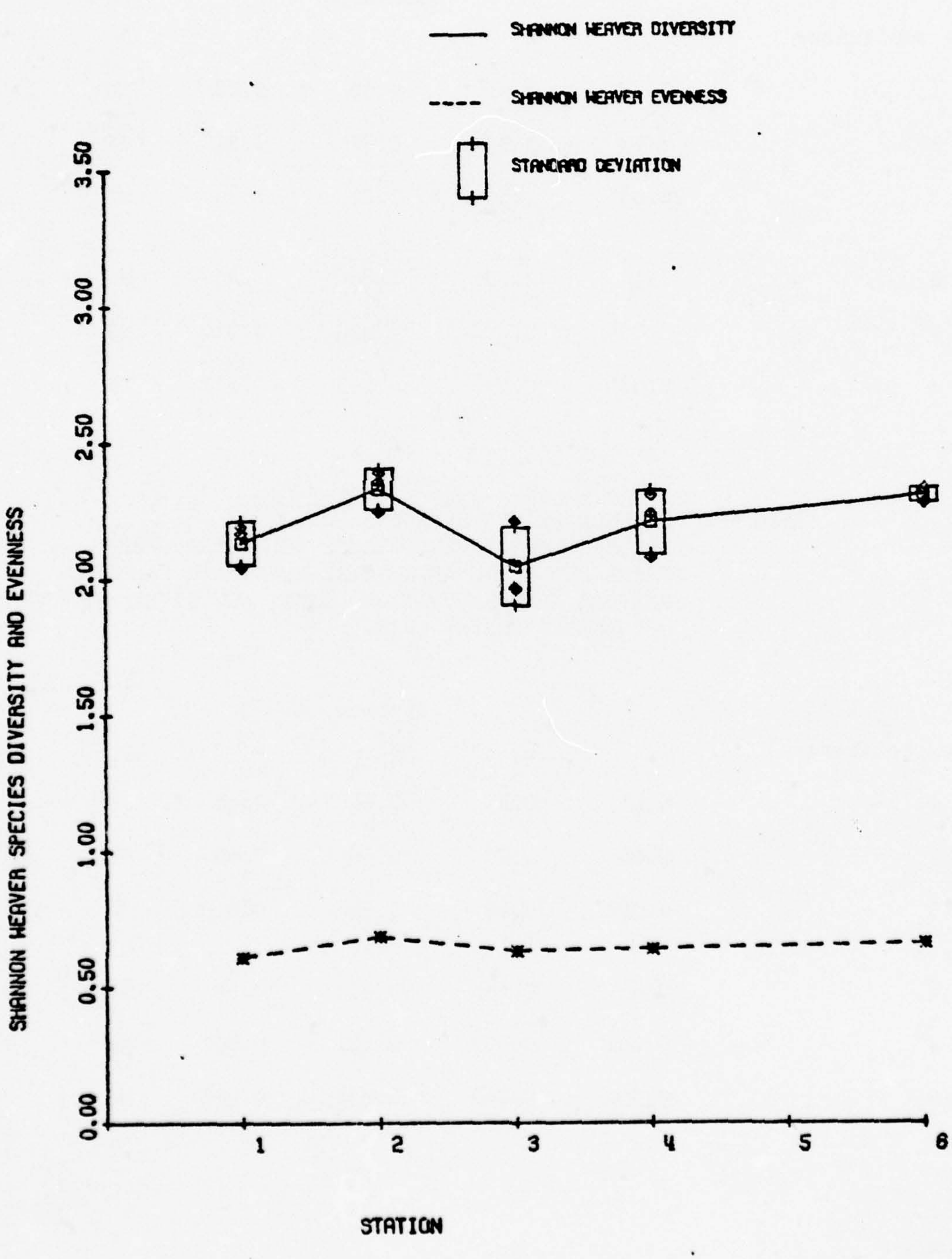


Figure 58.

STATION R1-RAAP BENTHOS-COMPARISON OF ART. SUB. BASKET REP. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

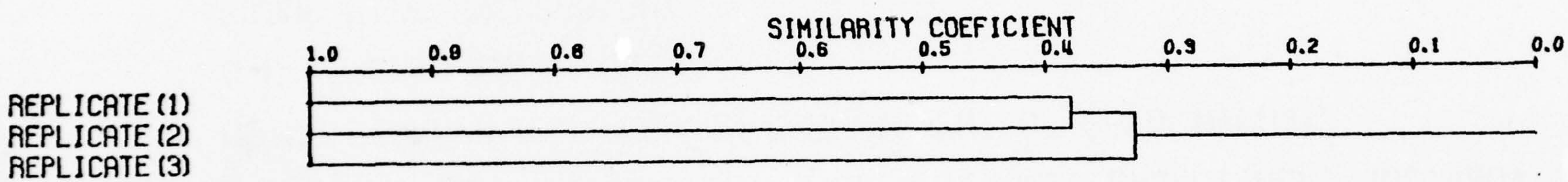
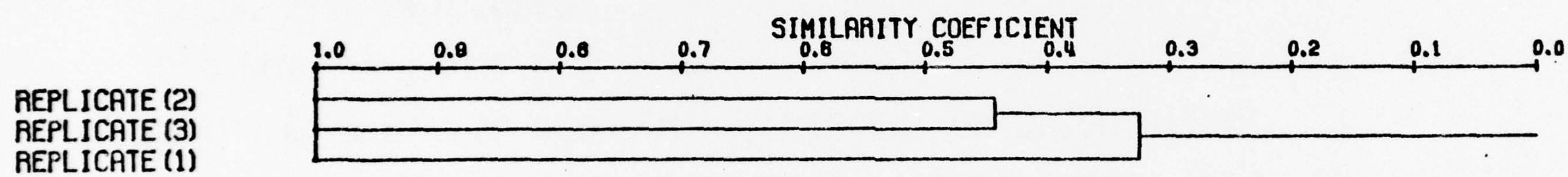


Figure 59.
STATION R2-RAAP BENTHOS-COMPARISON OF ART. SUB. BASKET REP. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



3. At station R-3 two replicates were similar at 43 percent while all three samples were similar at about 38 percent (Figure 60).
4. Nearly identical was the trend at station R-4 (Figure 61). The three replicates were similar at 31 percent while two samples were more similar at 45 percent.
5. Lowest levels of replication were seen at station R-6 (Figure 62). Two samples were similar at 39 percent while overall similarity was about 26 percent.

Since sample replication was not high there was good reason to combine species data from replicates for station-to-station comparisons. This would provide a broader species base for comparison between these stations.

As seen during the spring survey near adjacent station pairs had high similarity, i.e., R-1/R-2, R-2/R-3, and R-3/R-4 (Table 68). Highest similarity was in the area of industrial waste discharge, e.g., station R-2, R-3, and R-4. This resulted in stations R-2, R-3, and R-4 pairing together in a dendogram (Figure 63). The pairs of R-2 and R-4 were similar at the 55 percent level with station R-3 being similar to this pair at 54 percent (Table 68 and Figure 63). Station R-1 was similar to this group at 50 percent while station R-6 was least similar to all stations at about 40 percent.

A dominant species complex was characteristic to the five stations from which artificial substrates were collected. (Appendix XV). Five taxa were common, comprising 81 percent of the population at station R-1. Hyalella sp. and Stenonema (pulchellum group) occurred at a frequency of 22 and 19 percent respectively. Hydropsyche sp. (15 percent), Stenonema (interpunctatum group) (14 percent), and Ephemerella deficiens (11 percent) were also common.

Figure 60.

STATION R3-RAAP BENTHOS-COMPARISON OF ART. SUB. BASKET REP. (OCT-NOV 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT

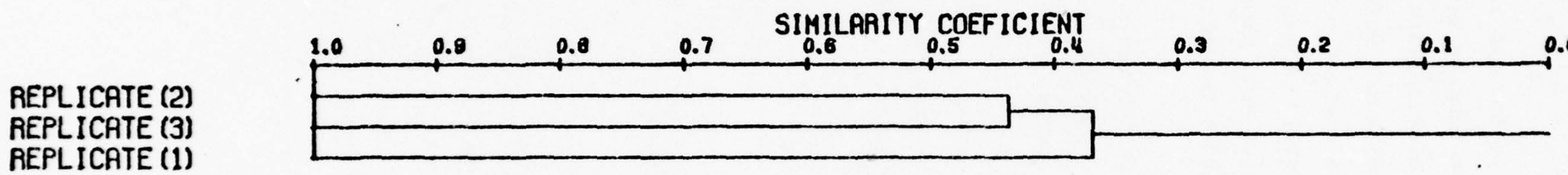


Figure 61.

STATION R4-RAAP BENTHOS-COMPARISON OF ART. SUB. BASKET REP. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT

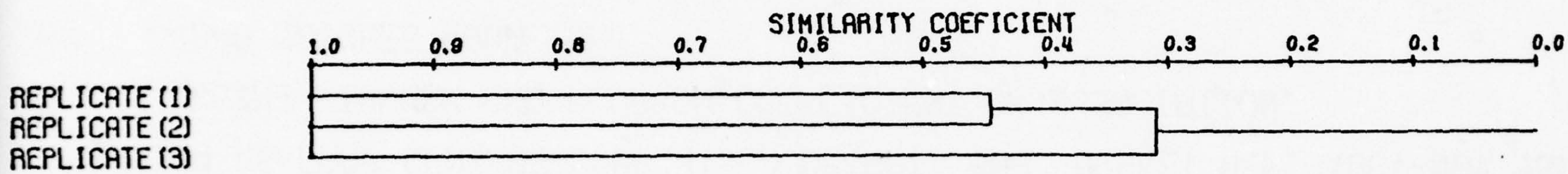


Figure 62.

STATION R6-RAAP BENTHOS-COMPARISON OF ART. SUB. BASKET REP. (OCT-NOV 75)

USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,

0-0 MATCHES EQUAL ONE

GROUP SIZE UNIMPORTANT



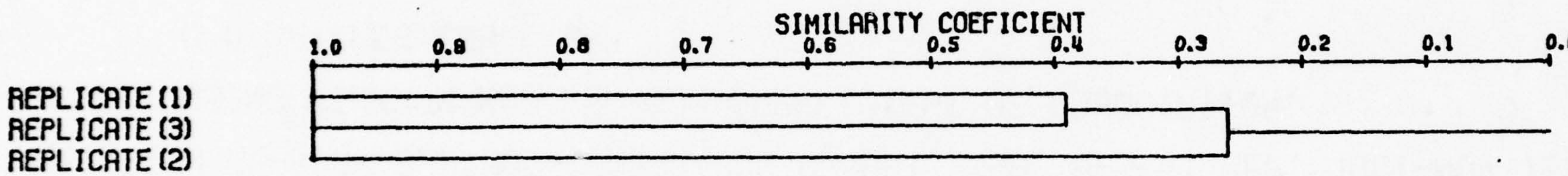


Table 68. COEFFICIENT OF ASSOCIATION OF BENTHIC MACROINVERTEBRATES ON ARTIFICIAL SUBSTRATES BETWEEN STATIONS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER, 1975.

| Station | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | |
| 2 | 0.523 | 1.000 | | | | |
| 3 | 0.497 | 0.542 | 1.000 | | | |
| 4 | 0.512 | 0.554 | 0.538 | 1.000 | | |
| 5 | NS* | NS | NS | NS | NS | |
| 6 | 0.374 | 0.291 | 0.462 | 0.407 | NS | 1.000 |

*No sample

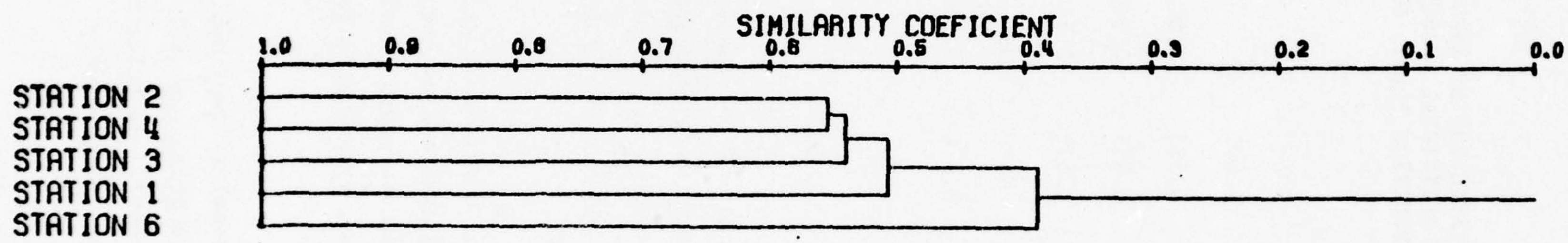
Sixty-nine percent of the population at station R-2 was comprised of five taxa. Most common was *Stenonema* (pulchellum group) (24 percent) while *S.* (interpunctatum group) occurred at 7 percent. Other common taxa included: *Hydropsyche* sp. - 16 percent, *Ephemerella deficiens* - 14 percent, and *Hyalella* sp. - 8 percent.

These same taxa comprised 73 percent of the benthos population at station R-3. *Stenonema* (pulchellum group) and *S.* (interpunctatum group) occurred at 38 and 10 percent respectively. Common to a lesser degree were: *Hydropsyche* sp. - 10 percent, *Ephemerella deficiens* - 9 percent, and *Hyalella* sp. - 6 percent.

Likewise this complex comprised 75 percent of the population at station R-4. Most common were *Stenonema* (pulchellum group) (31 percent) and *S.* (interpunctatum group) (13 percent). *Hyalella* sp. and *Ephemerella deficiens* were common at 13 and 11 percent respectively. Least common was *Hydropsyche* sp. at 7 percent.

Figure 63.

RAAP BENTHOS-STATION COMPARISON OF ART. SUB.-COMBINED REP. (OCT-NOV 75)
USING PINKHAM AND PEARSON COEFFICIENT OF ASSOCIATION,
0-0 MATCHES EQUAL ONE
GROUP SIZE UNIMPORTANT



A minor shift in the benthos population occurred at station R-6. Six taxa comprised 75 percent of the species complex. Stenonema (pulchellum group) remained dominant at 34 percent. Isonychia sp. 2, which had not been common at previous stations, and Hyalella sp. occurred at 11 and 10 percent respectively. Other common taxa were: Ephemerella deficiens - 9 percent, Hydropsyche sp. - 7 percent, and S. (interpunctatum group) - 4 percent, was occasional.

These data indicate that a dominant species complex occurred on artificial substrates at all stations. Minor shifts in frequency occurred within this complex but there were no drastic changes. Variations in species diversity and population similarity between stations was the result of the loss and recurrence of taxa occurring at a low frequency, i.e., occasional and rare taxa. The impact of these variations on population stability are minimal and no detrimental affects or variations were observed.

Species Occurrence on Natural Substrates (October-November, 1975) - Species data from natural substrates was not used for extensive trend analysis during the fall survey. Although five replicate samples were collected at each station only single samples were processed and identified. This was done merely to provide species data to compare to artificial substrate populations. Since it was found that the natural substrate collections did not truly reflect the conditions of the study area, i.e., were influenced by waste discharges other than from the Nitroglycerin No. 2 area, greater emphasis was placed on the artificial substrate data.

Similarity of the benthos populations between stations was low. Greatest similarity was built around station R-2 which was similar to station R-3 at 55 percent, station R-4 at 51 percent, and station R-6 at 57 percent. Lowest similarity occurred in combinations with station R-1, the reference station (Table 69). Adjacent stations pairs were similar around the 50 percent level except station pair R-1/R-2 (40 percent). This suggests a stress factor which occurs between stations R-1 and R-2, and continues through station R-6.

Table 69. COEFFICIENT OF ASSOCIATION OF BENTHIC MACROINVERTEBRATES ON NATURAL SUBSTRATES BETWEEN STATIONS. RADFORD ARMY AMMUNITION PLANT, NEW RIVER, VIRGINIA. OCTOBER-NOVEMBER , 1975.

| Stations | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | |
| 2 | 0.396 | 1.000 | | | | |
| 3 | 0.413 | 0.547 | 1.000 | | | |
| 4 | 0.324 | 0.514 | 0.463 | 1.000 | | |
| 5 | NS* | NS | NS | NS | NS | |
| 6 | 0.312 | 0.568 | 0.488 | 0.477 | NS | 1.000 |

*No samples

The dominant species complex was similar to that seen on artificial substrates although the dominant taxon was more common in proportion to the other taxa. On artificial substrates the common taxa were near equal in frequency. (Appendix XVI).

At station R-1 there were four taxa comprising 70 percent of the benthos population. Hyalella sp. was very common at 30 percent while Hydropsyche sp., Stenonema (pulchellum, group) and Limnodrilus sp. were common at 17, 12, and 11 percent respectively.

A slight shift in the species dominance occurred at station R-2. Sixty-eight percent of the population was of four taxa. Most common were Hydropsyche sp. and Stenonema (pulchellum group) at 29 and 21 percent respectively. Occurring at a lower frequency were Hyalella sp. (13 percent) and Limnodrilus sp. (5 percent).

Stenonema (pulchellum group) was the most common taxon at station R-3. Other common taxa were: Hyalella sp. - 17 percent, Hydropsyche sp. - 16 percent, and Limnodrilus sp. - 9 percent. This complex comprised 65 percent of the population at this station.

A significant shift occurred at station R-4. Two taxa, Stenonema (pulchellum group) (49 percent) and Hydropsyche sp. (19 percent), comprised 68 percent of the population at this station.

The dominant species complex was more diverse at station R-6 where four taxa comprised 67 percent of the population. These were: Hydropsyche sp. - 30 percent, Stenonema (pulchellum group) - 18 percent, Sphaerium sp. - 11 percent, and Hyalella sp. - 8 percent.

Species occurrence on natural substrates during the fall survey exhibited major shifts in relative abundance. This was not as obvious during the spring survey. Also during the fall survey there were taxa which were overwhelming dominants to the other common taxa.

Although during the fall survey there was a similarity between the dominant species complex on both natural and artificial substrates there appeared to be greater stability in the population on artificial substrates. This is indicated by the near equal frequency of occurrence within the dominant species complex as well as the occurrence of only minor species shifts.

Discussion of Results (October-November, 1975)

Species diversity of the benthic macroinvertebrate population varied slightly between station R-2, R-3 and R-4 during October-November, 1975. In looking at the species complex it was found that the common species remained constant throughout the study area. This held true on both artificial and natural substrates with minor exceptions. Some major shifts in dominance

did occur on natural substrates. Species dominance on both substrate types was comprised of species which are facultative and intorlerant to organic pollution[37]. Similar to the spring survey population structure was most similar in the area of known industrial waste discharge, and the areas of potential stress showed the greatest similarity between stations. Most reliable comparisons were drawn from the artificial substrates due to the location of natural substrate collection as explained previously.

The variation of water and sediment chemistry was not great during the fall survey. This made the explanation of benthic population variation difficult. Through the study area aqueous phase nitrogen forms, TOC, total phosphorus, chromium, and nitroglycerin increased with distance downstream. Levels of lead and TOC were not necessarily discharged from the Nitroglycerin No. 2 area and were mostly background concentrations.

During October there was an increase in nitrate and total Kjeldahl nitrogen through station R-4. It was found that most of these nitrogen forms were discharged from outfalls 18 and 19 of the Nitroglycerin No. 2 area. Chromium was found during the October survey but it did not increase in concentration through this area and it is not directly related to the production of nitroglycerin. Nitroglycerin was also discharged through outfalls 18 and 19 although levels were lower than recorded during May.

Similar to the May-June survey the observed variations in water and sediment chemistry during the fall were minimal and were not of a detrimental magnitude. There were variations in the populations of benthos macroinvertebrates which can be associated with the changes in water chemistry. These population changes were, however, insignificant and are not the direct result of industrial waste discharges from the Nitroglycerin No. 2 area. The benthos population within the study area was stable, varied slightly, but recovered from any minor affects which may have been associated with waste discharge into the New River.

## SECTION VIII

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SECTION IX

APPENDICES

APPENDIX 0: Radford Army Ammunition Plant
Sample Summary

RIVER STATIONS

Station R-1, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 5 | 0 | 0 |
| Artificial Substrates | 6 | 6 | 5 | 0 | 1 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 5 | 0 | 0 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |

Station R-1, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 1 | 0 | 4 |
| Artificial Substrates | 5 | 5 | 3 | 0 | 2 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 3 | 0 | 2 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 8 | 8 | 8 | 0 | 0 |
| Sediment Chemistry | 2 | 2 | 2 | 0 | 0 |

Station R-2, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 5 | 0 | 0 |
| Artificial Substrates | 6 | 6 | 5 | 0 | 1 |

APPENDIX 0 (Continued)

Station R-2, May-June, 1975 (Continued)

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 5 | 0 | 0 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 0 | 0 | 0 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station R-2, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 1 | 0 | 4 |
| Artificial Substrates | 5 | 5 | 3 | 0 | 2 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 0 | 0 | 5 | 0 |
| Chlorophyll | 5 | 0 | 0 | 5 | 0 |
| Organic Biomass | 5 | 0 | 0 | 5 | 0 |
| Aqueous Chemistry | 1 | 1 | 1 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |

Station R-3, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrates | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 5 | 0 | 0 |
| Artificial Substrates | 6 | 6 | 5 | 0 | 1 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 5 | 0 | 0 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 5 | 4 | 4 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 + 2 | 0 | 0 |

APPENDIX O: (Continued)

Station R-3, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrates | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 1 | 0 | 4 |
| Artificial Substrates | 6 | 5 | 3 | 0 | 3 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 3 | 0 | 2 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 0 | 0 | 0 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |

Station R-4, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrates | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 5 | 0 | 0 |
| Artificial Substrates | 6 | 6 | 5 | 0 | 1 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 5 | 0 | 0 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 + 1 | 0 | 0 |

Station R-4, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrates | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 1 | 0 | 4 |
| Artificial Substrates | 6 | 6 | 3 | 0 | 3 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 0 |
| Artificial Substrates | 5 | 5 | 3 | 0 | 2 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |

APPENDIX O: (Continued)

Station R-5, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 6 | 0 | 0 | 6 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 0 | 0 | 5 | 0 |
| Chlorophyll | 5 | 0 | 0 | 5 | 0 |
| Organic Biomass | 5 | 0 | 0 | 5 | 0 |
| Aqueous Chemistry | 5 | 4 | 4 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |

Station R-5, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrates | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 4 | 4 | 4 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |

Station R-6, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 5 | 0 | 0 |
| Artificial Substrates | 6 | 6 | 5 | 0 | 1 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 5 | 5 | 0 | 0 |
| Chlorophyll | 5 | 5 | 5 | 0 | 0 |
| Organic Biomass | 5 | 5 | 5 | 0 | 0 |

APPENDIX O: (Continued)

Station R-6, May-June, 1975 (Continued)

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 + 2 | 0 | 0 |
| | | | | | |
| **Station R-6, October-November, 1975** | | | | | |
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 5 | 5 | 1 | 0 | 4 |
| Artificial Substrates | 6 | 6 | 3 | 0 | 3 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 3 | 3 | 2 | 0 | 1 |
| Artificial Substrates | 5 | 3 | 3 | 2 | 0 |
| Chlorophyll | 5 | 3 | 3 | 2 | 0 |
| Organic Biomass | 5 | 3 | 3 | 2 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 3 | 3 | 3 | 0 | 0 |
| | | | | | |
| **INDUSTRIAL OUTFALLS** | | | | | |
| **Station I-18, May-June, 1975** | | | | | |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| | | | | | |
| **Station I-18, October-November, 1975** | | | | | |
| Aqueous Chemistry | 5 | 5 | 5 | 5 | 5 |
| | | | | | |
| **Station I-19, May-June, 1975** | | | | | |
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |

APPENDIX O: (Continued)

Station I-19, May-June, 1975 (Continued)

| Parameter | Attempted | Collected | Analyzed & Subsamples | Lost | Stored |
|---|---|---|---|---|---|
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station I-19, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsamples | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrates | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station I-20, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsamples | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station I-20, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsamples | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |

APPENDIX O: (Continued)

Station I-20, October-November, 1975 (Continued)

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station I-21, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 1 | 1 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station I-21, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 4 | 4 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

APPENDIX O: (Continued)

Station I-22, May-June, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 5 | 5 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

Station I-22, October-November, 1975

| Parameter | Attempted | Collected | Analyzed & Subsampled | Lost | Stored |
|---|---|---|---|---|---|
| Benthic Macroinvertebrate | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Periphyton | | | | | |
| Species Identification | | | | | |
| Natural Substrates | 0 | 0 | 0 | 0 | 0 |
| Artificial Substrates | 0 | 0 | 0 | 0 | 0 |
| Chlorophyll | 0 | 0 | 0 | 0 | 0 |
| Organic Biomass | 0 | 0 | 0 | 0 | 0 |
| Aqueous Chemistry | 5 | 4 | 4 | 0 | 0 |
| Sediment Chemistry | 0 | 0 | 0 | 0 | 0 |

APPENDIX I

RADFORD ARMY AMMUNITION PLANT
Claytor Reservoir Discharge Data

The following two pages list hourly discharges in cubic feet per second on selected days at Claytor Reservoir. The data was made available by the Appalachian Power Company, Roanoke, Virginia.

The time of passage from Claytor Reservoir to the RAAP is approximately four hours. Discharge rates that correspond to chemistry river sampling times (taking into account the four hour delay), are outlined.

In May, the flows at sampling time average 2818 cfs (79.80 cms) but ranged from 700 cfs (19.82 cms) to 7000 cfs (198.24 cms). During the Fall Survey, daytime sampling flows ranged from 3000 cfs (84.96 cms) to 6000 cfs (169.92 cms), with an average of 4919 cfs (139.31 cms). During nighttime sampling, the average flow was 1587 cfs (44.94 cms), with a range of 700 cfs (19.82 cms) to 2000 cfs (56.64 cms).

APPENDIX I -1
RADFORD ARMY AMMUNITION PLANT
Claytor Plant Discharge Data
(Cubic Feet Per Second)
1975

| Hour | May 15 | May 16 | May 17 | May 18 | May 19 | May 20 | May 21 | May 22 |
|---|---|---|---|---|---|---|---|---|
| 0100 | 789 | 9737 | 789 | 2105 | 5526 | 4211 | 789 | 789 |
| 0200 | 789 | 9474 | 526 | 789 | 2105 | 2105 | 789 | 789 |
| 0300 | 526 | 6579 | 789 | 526 | 2105 | 2105 | 789 | 789 |
| 0400 | 789 | 5000 | 789 | 789 | 2105 | 2368 | 526 | 526 |
| 0500 | 789 | 5526 | 526 | 789 | 2105 | 2105 | 789 | 789 |
| 0600 | 526 | 5000 | 789 | 789 | 2105 | 2105 | 789 | 2632 |
| 0700 | 789 | 5132 | 789 | 526 | 2105 | 2368 | 3684 | 2632 |
| 0800 | 2105 | 4474 | 526 | 789 | 2895 | 2895 | 5263 | 7368 |
| 0900 | 6053 | 4211 | 4474 | 5526 | 8421 | 7237 | 7368 | 8158 |
| 1000 | 7105 | 2632 | 9474 | 6842 | 8158 | 6053 | 8421 | 8684 |
| 1100 | 8947 | 2895 | 8421 | 8684 | 8947 | 7105 | 9737 | 8421 |
| 1200 | 7895 | 3158 | 7632 | 8947 | 7895 | 7895 | 8684 | 7368 |
| 1300 | 8684 | 3158 | 9474 | 8947 | 8684 | 7895 | 9474 | 8421 |
| 1400 | 8158 | 3421 | 6316 | 7895 | 8947 | 7368 | 9868 | 7895 |
| 1500 | 7632 | 3947 | 3947 | 9211 | 8421 | 8684 | 9474 | 7895 |
| 1600 | 9211 | 2368 | 2895 | 8684 | 7632 | 6579 | 6053 | 5789 |
| 1700 | 10000 | 3289 | 4737 | 8947 | 8158 | 7632 | 8421 | 6842 |
| 1800 | 9737 | 3026 | 3684 | 7895 | 7105 | 5789 | 5789 | 7105 |
| 1900 | 9474 | 4474 | 4211 | 7368 | 7368 | 5789 | 6053 | 6316 |
| 2000 | 10000 | 2895 | 5263 | 7895 | 7105 | 5526 | 5526 | 5789 |
| 2100 | 10000 | 3684 | 4211 | 8684 | 8158 | 8421 | 6316 | 6316 |

APPENDIX I-1 Continued

| Hour | May 15 | May 16 | May 17 | May 18 | May 19 | May 20 | May 21 | May 22 |
|---|---|---|---|---|---|---|---|---|
| 2200 | 9737 | 7895 | 4474 | 9474 | 9211 | 8421 | 7105 | 6316 |
| 2300 | 9474 | 5789 | 3947 | 7105 | 6579 | 4211 | 3421 | 2895 |
| 2400 | 9737 | 3158 | 4737 | 6053 | 6316 | 2368 | 2368 | 789 |

APPENDIX I-2.
RADFORD ARMY AMMUNITION PLANT
Claytor Plant Discharge Data
(Cubic Feet Per Second)
1975

| Hour | Oct. 30 | Oct. 31 | Nov. 1 | Nov. 2 | Nov. 3 | Nov.4 |
|---|---|---|---|---|---|---|
| 0100 | 789 | 789 | 789 | 526 | 789 | 526 |
| 0200 | 526 | 526 | 789 | 789 | 789 | 789 |
| 0300 | 789 | 789 | 526 | 789 | 526 | 526 |
| 0400 | 526 | 526 | 789 | 526 | 789 | 789 |
| 0500 | 789 | 789 | 526 | 789 | 526 | 789 |
| 0600 | 789 | 789 | 789 | 789 | 789 | 526 |
| 0700 | 526 | 526 | 526 | 526 | 789 | 789 |
| 0800 | 2895 | 3421 | 789 | 789 | 3421 | 2895 |
| 0900 | 5526 | 3421 | 789 | 526 | 7105 | 6053 |
| 1000 | 6579 | 5789 | 3553 | 789 | 5526 | 4474 |
| 1100 | 5263 | 5526 | 4474 | 789 | 4737 | 5263 |
| 1200 | 5526 | 5526 | 4474 | 526 | 5263 | 4737 |
| 1300 | 5658 | 3158 | 2368 | 789 | 6316 | 5526 |
| 1400 | 5526 | 1579 | 526 | 789 | 3026 | 3421 |
| 1500 | 2632 | 1842 | 789 | 526 | 789 | 789 |
| 1600 | 2105 | 2105 | 789 | 789 | 789 | 789 |
| 1700 | 2105 | 2105 | 526 | 789 | 526 | 526 |
| 1800 | 2105 | 2632 | 789 | 526 | 789 | 789 |
| 1900 | 2632 | 5000 | 789 | 789 | 2105 | 1316 |
| 2000 | 4737 | 5263 | 526 | 1579 | 3421 | 4474 |

APPENDIX I-2 Continued

| Hour | Oct. 30 | Oct. 31 | Nov. 1 | Nov. 2 | Nov. 3 | Nov.4 |
|---|---|---|---|---|---|---|
| 2100 | 6316 | 5395 | 789 | 3421 | 3421 | 5000 |
| 2200 | 6053 | 3947 | 526 | 5263 | 3684 | 4737 |
| 2300 | 2632 | 789 | 789 | 1053 | 2632 | 789 |
| 2400 | 789 | 526 | 789 | 526 | 789 | 526 |

APPENDIX II-1

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Station
15 May 1975

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Specific Conductance | μmhos/cm | 4030 | 1760 | 3530 | - | 311 |
| Total Solids | mg/l | 5310 | 1860 | 3180 | - | 439 |
| Total Suspended Solids | mg/l | 20 | 6 | 9 | - | 10 |
| pH | SU | 8.50 | 10.50 | 10.50 | - | 9.20 |
| Total Alkalinity | mg/l as $CaCO_3$ | 531 | 1500 | 2570 | - | 165 |
| Chloride | mg/l | 25.2 | 19.7 | 31.7 | - | 9.2 |
| Sulfate | mg/l | 63 | 44 | 29 | - | 10 |
| Total Hardness | mg/l as $CaCO_3$ | 49 | 22 | 25 | - | 37 |
| Calcium | mg/l | 12.5 | 2.9 | 3.8 | - | 8.8 |
| Magnesium | mg/l | 4.3 | 3.5 | 3.7 | - | 3.7 |
| Sodium | mg/l | 1460 | 810 | 1360 | - | 84.8 |
| Potassium | mg/l | 7.8 | 6.3 | 7.3 | - | 4.7 |
| Dissolved Oxygen | mg/l | 8.6 | 9.0 | 6.6 | - | 8.1 |
| BOD | mg/l | 2 | 14 | 226 | - | 260 |
| COD | mg/l | 127 | 144 | 776 | - | 1350 |
| TOC | mg/l | 54 | 50 | 120 | - | 280 |
| Kjeldahl-N | mg/l | <0.2 | 0.4 | 1.5 | - | 3.6 |
| Ammonia-N | mg/l | 0.13 | 0.12 | 0.25 | - | 0.12 |

APPENDIX II-1 Continued

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Nitrite-N | mg/1 | 0.21 | 0.86 | 3.3 | - | 2.8 |
| Nitrate-N | mg/1 | 970 | 20 | 25 | - | 55 |
| Total Phosphorus | mg/1 | 0.006 | 0.36 | 0.008 | - | 0.46 |
| Cadmium | mg/1 | <0.0001 | <0.0001 | 0.0002 | - | 0.0002 |
| Chromium | mg/1 | 0.035 | 0.011 | 0.011 | - | 0.001 |
| Iron | mg/1 | 0.21 | 0.16 | 0.054 | - | 0.26 |
| Lead | mg/1 | 0.590 | 0.026 | 0.095 | - | 2.6 |
| Manganese | mg/1 | 0.003 | 0.002 | 0.001 | - | 0.011 |
| Mercury | mg/1 | 0.0002 | <0.0001 | <0.0001 | - | 0.0001 |

APPENDIX II-2

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

16 May 1975

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Specific Conductance | µmhos/cm | 5500 | 5800 | 21000 | - | 238 |
| Total Solids | mg/l | 4840 | 4910 | 17700 | - | 296 |
| Total Suspended Solids | mg/l | 16 | 19 | 36 | - | 10 |
| pH | SU | 9.50 | 10.40 | 10.30 | - | 6.55 |
| Total Alkalinity | mg/l as $CaCO_3$ | 1060 | 3410 | 13090 | - | 66 |
| Chloride | mg/l | 34.4 | 30.7 | 67.5 | - | 13.2 |
| Sulfate | mg/l | 56 | 87 | 300 | - | 51 |
| Total Hardness | mg/l as $CaCO_3$ | 23 | 25 | 32 | - | 40 |
| Calcium | mg/l | 2.2 | 3.3 | 6.2 | - | 9.8 |
| Magnesium | mg/l | 4.2 | 4.1 | 4.0 | - | 3.9 |
| Sodium | mg/l | 1420 | 1990 | 7500 | - | 48.3 |
| Potassium | mg/l | 7.9 | 8.0 | 39 | - | 4.6 |
| Dissolved Oxygen | mg/l | 8.5 | 9.2 | 4.1 | - | 8.6 |
| BOD | mg/l | 14 | 63 | >2250 | - | 342 |
| COD | mg/l | 112 | 106 | 4060 | - | 383 |
| TOC | mg/l | - | 110 | 360 | - | 180 |
| Kjeldahl-N | mg/l | <0.2 | 0.4 | 4.6 | - | 2.7 |
| Ammonia-N | mg/l | 0.081 | 0.34 | 1.8 | - | 0.11 |

APPENDIX II-2 Continued

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Nitrite-N | mg/l | 0.36 | 1.5 | 21 | - | 0.38 |
| Nitrate-N | mg/l | 750 | 220 | 0.18 | - | 48 |
| Total Phosphorus | mg/l | 0.003 | 0.002 | 0.017 | - | 0.38 |
| Cadmium | mg/l | <0.0001 | <0.0001 | 0.0026 | - | 0.0002 |
| Chromium | mg/l | 0.099 | 0.007 | 0.003 | - | 0.006 |
| Iron | mg/l | 0.066 | 0.056 | 0.14 | - | 0.14 |
| Lead | mg/l | 0.190 | 0.031 | 0.124 | - | 1.5 |
| Manganese | mg/l | 0.001 | 0.001 | 0.004 | - | 0.005 |
| Mercury | mg/l | <0.0001 | <0.0001 | 0.0003 | - | 0.0007 |

APPENDIX II-3

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

17 May 1975

| Parameters | Units | Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | I18 (Prod.) | I18 (No Prod.) | I19 | I20 | I21 | I22 (Prod.) | I22 (No Prod.) |
| Specific Conductance | µmhos/cm | 4200 | 900 | 9700 | 13000 | - | 160 | 230 |
| Total Solids | mg/l | 4970 | 2040 | 13300 | 19800 | - | 225 | 374 |
| Total Suspended Solids | mg/l | 16 | 10 | 35 | 46 | - | 12 | 7 |
| pH | SU | 8.90 | 9.40 | 10.75 | 10.60 | - | 8.00 | 7.30 |
| Total Alkalinity | mg/l as $CaCO_3$ | 505 | 390 | 9430 | 16430 | - | 8.5 | 111 |
| Chloride | mg/l | 22.7 | 15.0 | 62.4 | 87.2 | - | 9.1 | 5.9 |
| Sulfate | mg/l | 75 | 40 | 120 | 92 | - | 42 | 72 |
| Total Hardness | mg/l as $CaCO_3$ | 48 | 49 | 27 | 31 | - | 44 | 58 |
| Calcium | mg/l | 12.3 | 12.6 | 4.2 | 5.6 | - | 10.6 | 14.0 |
| Magnesium | mg/l | 4.2 | 4.2 | 4.0 | 4.2 | - | 4.3 | 5.6 |
| Sodium | mg/l | 1400 | 580 | 5550 | 8400 | - | 42.5 | 55.6 |
| Potassium | mg/l | 7.5 | 5.8 | 3.5 | 43 | - | 3.8 | 4.3 |
| Dissolved Oxygen | mg/l | 8.2 | 8.1 | 6.3 | 3.2 | - | 9.8 | 9.5 |
| BOD | mg/l | - | 12 | 183 | 244 | - | 318 | 455 |
| COD | mg/l | 134 | 30 | 458 | 527 | - | 971 | - |
| TOC | mg/l | 49 | 46 | 180 | 430 | - | 250 | 200 |
| Kjeldahl-N | mg/l | <.2 | 0.2 | 4.4 | 8.2 | - | 3.8 | 4.1 |
| Ammonia-N | mg/l | 0.10 | 0.069 | 0.60 | 0.57 | - | 0.084 | 0.12 |

APPENDIX II-3 Continued

| Parameter | Units | Stations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | I18 (Prod.) | I18 (No Prod.) | I19 | I20 | I21 | I22 (Prod.) | I22 (No Prod.) |
| Nitrite-N | mg/l | 0.31 | 0.19 | 14 | 34 | - | 0.21 | 0.031 |
| Nitrate-N | mg/l | 610 | 180 | 440 | 230 | - | 84 | 33 |
| Total Phosphorus | mg/l | 0.010 | 0.006 | 0.017 | 0.009 | - | 0.066 | 0.038 |
| Cadmium | mg/l | 0.0002 | 0.0001 | 0.0011 | 0.0008 | - | 0.0003 | 0.0006 |
| Chromium | mg/l | 0.122 | 0.019 | 0.011 | 0.026 | - | 0.007 | 0.009 |
| Iron | mg/l | 0.090 | 0.088 | 0.094 | 0.080 | - | 0.14 | 0.12 |
| Lead | mg/l | 0.082 | 0.290 | 0.116 | 0.026 | - | 1.4 | 2.7 |
| Manganese | mg/l | 0.002 | 0.001 | 0.002 | 0.001 | - | 0.011 | 0.021 |
| Mercury | mg/l | 0.0059 | 0.060 | 0.0028 | 0.0018 | - | 0.006 | 0.0010 |

APPENDIX II-4

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

18 May 1975

| Parameters | Units | Stations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | I18 | I19 (Prod.) | I19 (No Prod.) | I20 (Prod.) | I20 (No Prod.) | I21 | I22 |
| Specific Conductance | μmhos/cm | 5800 | 9400 | 5400 | 9000 | 10600 | - | 142 |
| Total Solids | mg/1 | 5690 | 9700 | 4940 | 8250 | 10500 | - | 10.3 |
| Total Suspended Solids | mg/1 | 21 | 32 | 17 | 28 | 26 | - | 1 |
| pH | SU | 8.55 | 10.50 | 10.45 | 10.50 | 10.40 | - | 7.70 |
| Total Alkalinity | mg/1 as $CaCO_3$ | 515 | 7850 | 3880 | 6670 | 8150 | - | 80 |
| Chloride | mg/1 | 23.6 | 64.2 | 33.2 | 28.9 | 61.4 | - | 11.3 |
| Sulfate | mg/1 | 76 | 51 | 4 | 68 | 140 | - | 13 |
| Total Hardness | mg/1 as $CaCO_3$ | 40 | 32 | 32 | 29 | 30 | - | 41 |
| Calcium | mg/1 | 9.5 | 6.0 | 6.1 | 4.8 | 5.2 | - | 10.3 |
| Magnesium | mg/1 | 4.0 | 4.2 | 4.0 | 4.1 | 4.2 | - | 3.8 |
| Sodium | mg/1 | 1580 | 4190 | 2010 | 3590 | 4470 | - | 34.8 |
| Potassium | mg/1 | 7.8 | 33 | 8.4 | 10 | 33 | - | 3.4 |
| Dissolved Oxygen | mg/1 | 9.0 | 7.8 | 8.4 | 5.9 | 6.9 | - | - |
| BOD | mg/1 | <1 | 0 | 44 | 114 | 308 | - | 101 |
| COD | mg/1 | 45 | 360 | - | 590 | - | - | 215 |
| TOC | mg/1 | 47 | 250 | - | 130 | - | - | 64 |
| Kjeldahl-N | mg/1 | <0.2 | 4.3 | - | 3.3 | - | - | 1.9 |
| Ammonia-N | mg/1 | 0.11 | 1.2 | - | 0.76 | - | - | 0.12 |

APPENDIX II-4 Continued

| Parameters | Units | Stations | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | I18 | I19 (Prod.) | I19 (No Prod.) | I20 (Prod.) | I20 (No Prod.) | I21 | I22 |
| Nitrite-N | mg/l | 0.23 | 18 | - | 13 | - | - | 0.031 |
| Nitrate-N | mg/l | 840 | 72 | - | 46 | - | - | 33 |
| Total Phosphorus | mg/l | 0.004 | 0.011 | 0.016 | 0.011 | 0.022 | - | 0.079 |
| Cadmium | mg/l | 0.0004 | 0.0011 | 0.0001 | 0.0008 | 0.0007 | - | 0.0002 |
| Chromium | mg/l | 0.031 | 0.002 | 0.004 | 0.005 | 0.014 | - | 0.024 |
| Iron | mg/l | 0.094 | 0.060 | 0.064 | 0.048 | 0.066 | - | 0.060 |
| Lead | mg/l | 2.5 | 0.114 | 0.122 | 0.026 | 0.077 | - | 1.8 |
| Manganese | mg/l | 0.002 | 0.001 | 0.001 | 0.001 | 0.002 | - | 0.007 |
| Mercury | mg/l | 0.0005 | 0.0032 | 0.0004 | 0.0005 | <0.0001 | - | 0.0005 |

APPENDIX II-5

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

20 May 1975

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Specific Conductance | μmhos/cm | - | - | - | 342 | - |
| Total Solids | mg/l | - | - | - | 488 | - |
| Total Suspended Solids | mg/l | - | - | - | 69 | - |
| pH | SU | - | - | - | 9.52 | - |
| Total Alkalinity | mg/l as $CaCO_3$ | - | - | - | 108 | - |
| Chloride | mg/l | - | - | - | 18.3 | - |
| Sulfate | mg/l | - | - | - | 23 | - |
| Total Hardness | mg/l as $CaCO_3$ | - | - | - | 42 | - |
| Calcium | mg/l | - | - | - | 10.1 | - |
| Magnesium | mg/l | - | - | - | 4.1 | - |
| Sodium | mg/l | - | - | - | 36.1 | - |
| Potassium | mg/l | - | - | - | 18 | - |
| Dissolved Oxygen | mg/l | - | - | - | 7.1 | - |
| BOD | mg/l | - | - | - | 86 | - |
| COD | mg/l | - | - | 2980 | 258 | - |
| TOC | mg/l | - | 100 | 860 | 190 | - |
| Kjeldahl-N | mg/l | - | 0.3 | 7.3 | 4.5 | - |
| Ammonia-N | mg/l | - | 0.22 | 2.1 | 0.33 | - |

APPENDIX II-5 Continued

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Nitrite-N | mg/l | – | 1.3 | 3.4 | 0.35 | – |
| Nitrate-N | mg/l | – | 71 | 179 | 25 | – |
| Total Phosphorus | mg/l | – | 0.010 | 0.002 | 0.28 | – |
| Cadmium | mg/l | – | – | – | 0.0007 | – |
| Chromium | mg/l | – | – | – | 0.010 | – |
| Iron | mg/l | – | – | – | 0.15 | – |
| Lead | mg/l | – | – | – | 0.96 | – |
| Manganese | mg/l | – | – | – | 0.013 | – |
| Mercury | mg/l | – | – | – | 0.0001 | – |

APPENDIX II-6

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data
Industrial Stations
30 October 1975

| Parameter | Units | Station I18 (night) | I19 (night) | I20 (night) | I21 (day) | I22 (day) |
|---|---|---|---|---|---|---|
| Specific Conductance | µmhos/cm | 6500 | 331 | 12400 | 1020 | 298 |
| Total Solids | mg/l | 6380 | 245 | 13500 | 1450 | 420 |
| Total Suspended Solids | mg/l | 17 | 1 | 24 | 271 | 7 |
| pH | SU | 9.20 | 9.60 | 10.75 | 9.90 | 8.00 |
| Total Alkalinity | mg/l as $CaCO_3$ | 778 | 154 | 9830 | 682 | 142 |
| Chloride | mg/l | 40.3 | 20.7 | 163 | 54.2 | 12.0 |
| Sulfate | mg/l | 105 | 26 | 208 | 52 | 20 |
| Total Hardness | mg/l as $CaCO_3$ | 38 | 38 | 23 | 36 | 175 |
| Calcium | mg/l | 9.0 | 4.3 | 3.0 | 0.9 | 37.3 |
| Magnesium | mg/l | 3.8 | 6.6 | 3.7 | 8.2 | 19.9 |
| Sodium | mg/l | 1770 | 83 | 5350 | 305 | 26.0 |
| Potassium | mg/l | 9.0 | 4.1 | 30 | 17 | 3.8 |
| Dissolved Oxygen | mg/l | 9.4 | 9.7 | 9.4 | 9.8 | 9.9 |
| BOD | mg/l | 1 | 1 | 23 | 99 | 203 |
| COD | mg/l | 124 | 32 | 540 | 1100 | 720 |
| TOC | mg/l | 45 | 11 | 188 | 103 | 217 |
| Kjeldahl-N | mg/l | 0.5 | 0.1 | 4.6 | 13.7 | 2.4 |
| Ammonia-N | mg/l | 0.096 | 0.051 | 0.49 | 0.23 | 0.12 |
| Nitrite-N | mg/l | 0.51 | 0.27 | 14 | 0.078 | 0.26 |
| Nitrate-N | mg/l | 910 | 2.5 | 340 | 23 | 36 |
| Total Phosphorus | mg/l | 0.004 | 0.001 | 0.006 | 0.16 | $<0.001$ |

APPENDIX II-6 Continued

| Parameter | Units | I18 (night) | I19 (night) | I20 (night) | I21 (day) | I22 (day) |
|---|---|---|---|---|---|---|
| Cadmium | mg/l | <0.0001 | < 0.0001 | 0.0002 | 0.0001 | 0.0005 |
| Chromium | mg/l | 0.002 | 0.005 | 0.008 | 0.009 | 0.003 |
| Iron | mg/l | 0.067 | 0.013 | 0.23 | 0.20 | 0.096 |
| Lead | mg/l | 0.016 | <0.001 | 0.016 | 1.3 | 17 |
| Manganese | mg/l | 0.004 | 0.005 | 0.012 | 0.029 | 0.018 |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX II-7

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data
Industrial Stations
31 October 1975

| Parameter | Units | Station I18 (night) | I19 (night) | I 20 (night) | I21 (day) | I22 (day) |
|---|---|---|---|---|---|---|
| Specific Conductance | µmhos/cm | 6900 | 1180 | 11800 | 480 | 299 |
| Total Solids | mg/l | 6500 | 934 | 9830 | 796 | 523 |
| Total Suspended Solids | mg/l | 10 | 34 | 30 | 276 | 6 |
| pH | SU | 9.10 | 9.80 | 10.80 | 9.10 | 7.60 |
| Total Alkalinity | mg/l as $CaCO_3$ | 951 | 676 | 8050 | 344 | 136 |
| Chloride | mg/l | 41.0 | 32.9 | 161 | 22.8 | 13.7 |
| Sulfate | mg/l | 99 | 35 | 24 | 55 | 43 |
| Total Hardness | mg/l as $CaCO_3$ | 33 | 70 | 31 | 120 | 253 |
| Calcium | mg/l | 7.2 | 2.9 | 3.7 | 6.0 | 58.4 |
| Magnesium | mg/l | 3.7 | 15.3 | 5.4 | 25.5 | 26.0 |
| Sodium | mg/l | 1840 | 320 | 3950 | 98 | 9.5 |
| Potassium | mg/l | 9.1 | 5.0 | 27 | 8.6 | 3.3 |
| Dissolved Oxygen | mg/l | 9.2 | 9.2 | 9.1 | 10.1 | 11.8 |
| BOD | mg/l | 4 | 34 | 142 | 109 | 432 |
| COD | mg/l | 116 | 60 | 499 | 361 | 937 |
| TOC | mg/l | 40 | 21 | 177 | 47 | 263 |
| Kjeldahl-N | mg/l | <0.1 | <0.2 | 6.1 | 4.4 | 3.1 |
| Ammonia-N | mg/l | 0.090 | 0.11 | 0.70 | 0.14 | 0.11 |
| Nitrite-N | mg/l | 0.46 | 0.29 | 16 | 0.23 | 0.23 |
| Nitrate-N | mg/l | 810 | 10 | 160 | 18 | 57 |
| Total Phosphorus | mg/l | 0.003 | < 0.001 | < 0.001 | 0.009 | < 0.001 |

AD-A036 777 ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD, AND JOLIET ARMY AMMUNIT--ETC(U)
MAR 76 R L WEITZEL, R EISENMAN, J E SCHENK DAMD17-75-C-5046

UNCLASSIFIED NL

4 OF 5
ADA036777

APPENDIX II-7 Continued

| Parameter | Units | Station I18 (night) | I19 (night) | I20 (night) | I21 (day) | I22 (day) |
|---|---|---|---|---|---|---|
| Cadmium | mg/l | <0.0001 | 0.0001 | 0.0002 | <0.0001 | 0.0003 |
| Chromium | mg/l | 0.004 | 0.002 | 0.004 | 0.006 | 0.001 |
| Iron | mg/l | 0.12 | 0.034 | 0.080 | 0.14 | 0.099 |
| Lead | mg/l | 0.020 | 0.001 | 0.025 | 1.4 | 8.1 |
| Manganese | mg/l | 0.007 | 0.002 | 0.006 | 0.014 | 0.036 |
| Mercury | mg/l | 0.0006 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX II-8

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

1 November 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 (night) | I19 (night) | I20 (night) | I21 (day) | I22 (day) |
| Specific Conductance | μmhos/cm | 6000 | 1490 | 11900 | 376 | 397 |
| Total Solids | mg/l | 5960 | 1120 | 10500 | 1420 | 763 |
| Total Suspended Solids | mg/l | 12 | 4 | 14 | 902 | 66 |
| pH | SU | 9.45 | 10.30 | 10.70 | 8.00 | 8.40 |
| Total Alkalinity | mg/l as $CaCO_3$ | 637 | 744 | 9280 | 200 | 100 |
| Chloride | mg/l | 29.5 | 25.9 | 142 | 15.9 | 8.6 |
| Sulfate | mg/l | 123 | 42 | 32 | 58 | 22 |
| Total Hardness | mg/l as $CaCO_3$ | 27 | 36 | 30 | 194 | 266 |
| Calcium | mg/l | 3.4 | 3.2 | 2.4 | 29.9 | 62.0 |
| Magnesium | mg/l | 4.6 | 6.8 | 5.8 | 29.0 | 27.0 |
| Sodium | mg/l | 1730 | 430 | 4200 | 6.9 | 31.5 |
| Potassium | mg/l | 8.7 | 6.0 | 27 | 2.6 | 4.9 |
| Dissolved Oxygen | mg/l | 9.4 | 9.6 | 8.8 | 9.4 | 9.4 |
| BOD | mg/l | 1 | 5 | 75 | 7 | 530 |
| COD | mg/l | 98 | 35 | 1120 | 428 | 1670 |
| TOC | mg/l | 38 | 8 | 278 | 8 | 479 |
| Kjeldahl-N | mg/l | <0.2 | <0.1 | 3.5 | 6.0 | 3.4 |
| Ammonia-N | mg/l | 0.13 | 0.064 | 0.46 | 0.043 | 0.13 |

APPENDIX II-8 Continued

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 (night) | I19 (night) | I 20 (night) | I21 (day) | I22 (day) |
| Nitrite-N | mg/l | 0.45 | 0.74 | 12 | 0.010 | 0.66 |
| Nitrate-N | mg/l | 860 | 20 | 110 | 12 | 100 |
| Total Phosphorus | mg/l | 0.001 | 0.004 | <0.001 | 0.093 | 0.011 |
| Cadmium | mg/l | <0.0001 | 0.0002 | <0.0001 | 0.0002 | 0.0014 |
| Chromium | mg/l | 0.002 | 0.024 | 0.002 | 0.004 | 0.001 |
| Iron | mg/l | 0.097 | 0.034 | 0.059 | 0.097 | 0.10 |
| Lead | mg/l | 0.012 | 0.004 | 0.020 | 0.78 | 230 |
| Manganese | mg/l | 0.011 | 0.002 | 0.007 | 0.008 | 0.090 |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX II-9

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

3 November 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 (night) | I19 (night) | I 20 (night) | I21 | I22 |
| Specific Conductance | µmhos/cm | 4880 | 8800 | 3390 | - | - |
| Total Solids | mg/l | 4650 | 7530 | 2470 | - | - |
| Total Suspended Solids | mg/l | 13 | 10 | 4 | - | - |
| pH | SU | 8.80 | 10.70 | 10.40 | - | - |
| Total Alkalinity | mg/l as $CaCO_3$ | 339 | 5780 | 1870 | - | - |
| Chloride | mg/l | 25.2 | 115 | 67.1 | - | - |
| Sulfate | mg/l | 94 | 57 | 16 | - | - |
| Total Hardness | mg/l as $CaCO_3$ | 37 | 35 | 33 | - | - |
| Calcium | mg/l | 8.4 | 4.4 | 1.7 | - | - |
| Magnesium | mg/l | 4.0 | 5.9 | 7.1 | - | - |
| Sodium | mg/l | 1360 | 2900 | 1040 | - | - |
| Potassium | mg/l | 7.9 | 26 | 7.4 | - | - |
| Dissolved Oxygen | mg/l | 8.9 | 9.1 | 8.7 | - | - |
| BOD | mg/l | 2 | 43 | 25 | - | - |
| COD | mg/l | 103 | 578 | 130 | - | - |
| TOC | mg/l | 38 | 166 | 43 | - | - |
| Kjeldahl-N | mg/l | <0.2 | 2.0 | 1.8 | - | - |
| Ammonia-N | mg/l | 0.10 | 0.30 | 0.24 | - | - |

APPENDIX II-9 Continued

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 (night) | I19 (night) | I20 (night) | I21 | I22 |
| Nitrite-N | mg/l | 0.22 | 21 | 0.38 | - | - |
| Nitrate-N | mg/l | 730 | 92 | 34 | - | - |
| Total Phosphorus | mg/l | 0.001 | 0.011 | <0.001 | - | - |
| Cadmium | mg/l | <0.0001 | 0.0011 | <0.0001 | - | - |
| Chromium | mg/l | 0.004 | 0.013 | 0.004 | - | - |
| Iron | mg/l | 0.094 | 0.047 | 0.023 | - | - |
| Lead | mg/l | 0.11 | 0.039 | 0.002 | - | - |
| Manganese | mg/l | 0.009 | 0.006 | 0.004 | - | - |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 | - | - |

APPENDIX II-10

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

Industrial Stations

4 November 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 (day) | I19 (day) | I20 (day) | I21 (day) | I22 (day) |
| Specific Conductance | μmhos/cm | 5400 | 12900 | 2110 | 620 | 333 |
| Total Solids | mg/l | 6810 | 12500 | 1930 | 1300 | 636 |
| Total Suspended Solids | mg/l | 18 | 54 | 12 | 592 | 10 |
| pH | SU | 8.65 | 10.60 | 10.20 | 9.10 | 7.80 |
| Total Alkalinity | mg/l as $CaCO_3$ | 474 | 11100 | 1560 | 429 | 156 |
| Chloride | mg/l | 41.2 | 125 | 27.3 | 27.7 | 15.4 |
| Sulfate | mg/l | 114 | 64 | 37 | 148 | 52 |
| Total Hardness | mg/l as $CaCO_3$ | 41 | 50 | 47 | 123 | 252 |
| Calcium | mg/l | 9.3 | 3.9 | 1.1 | 3.0 | 56.7 |
| Magnesium | mg/l | 4.4 | 9.7 | 10.7 | 28.0 | 27.0 |
| Sodium | mg/l | 1970 | 5300 | 830 | 172 | 22.5 |
| Potassium | mg/l | 8.9 | 31 | 6.7 | 20 | 4.4 |
| Dissolved Oxygen | mg/l | 10.0 | 10.2 | 9.8 | 9.6 | 10.5 |
| BOD | mg/l | 2 | 67 | 32 | 145 | 510 |
| COD | mg/l | 163 | 626 | 165 | 720 | 1310 |
| TOC | mg/l | 47 | 186 | 54 | 106 | 379 |
| Kjeldahl-N | mg/l | <0.2 | 9.0 | 1.4 | 10.4 | 4.2 |
| Ammonia-N | mg/l | 0.10 | 0.97 | 0.14 | 0.27 | 0.19 |

APPENDIX II-10 Continued

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | I18 (day) | I19 (day) | I20 (day) | I21 (day) | I22 (day) |
| Nitrite-N | mg/1 | 0.28 | 2.6 | 0.32 | 0.10 | 2.3 |
| Nitrate-N | mg/1 | 910 | 170 | 23 | 18 | 75 |
| Total Phosphorus | mg/1 | 0.003 | 0.010 | 0.004 | 0.13 | <0.001 |
| Cadmium | mg/1 | <0.0001 | 0.0019 | <0.0001 | 0.0001 | 0.0004 |
| Chromium | mg/1 | 0.003 | 0.005 | 0.004 | 0.009 | 0.002 |
| Iron | mg/1 | 0.11 | 0.064 | 0.021 | 0.31 | 0.046 |
| Lead | mg/1 | 0.010 | 0.025 | 0.015 | 0.79 | 19 |
| Manganese | mg/1 | 0.005 | 0.006 | 0.003 | 0.031 | 0.041 |
| Mercury | mg/1 | 0.0002 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-1

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data
New River Stations
15 May 1975

| Parameter | Units | Stations R1 | R3 | R4 | R5 | R6 |
|---|---|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 70 | - | 68 | - | 72 |
| Total Solids | mg/l | 103 | - | 89 | - | 70 |
| Total Suspended Solids | mg/l | 2 | - | 2 | - | 2 |
| pH | SU | 8.30 | - | 7.70 | - | 8.00 |
| Total Alkalinity | mg/l as $CaCO_3$ | 38 | - | 31 | - | 42 |
| Choride | mg/l | 5.2 | - | 7.6 | - | 4.9 |
| Sulfate | mg/l | 11 | - | 17 | - | 11 |
| Total Hardness | mg/l as $CaCO_3$ | 38 | - | 40 | - | 41 |
| Calcium | mg/l | 8.7 | - | 9.6 | - | 10.0 |
| Magnesium | mg/l | 4.0 | - | 4.0 | - | 4.0 |
| Sodium | mg/l | 2.7 | - | 3.1 | - | 2.7 |
| Potassium | mg/l | 1.6 | - | 1.7 | - | 1.7 |
| Dissolved Oxygen | mg/l | 9.7 | - | 9.6 | - | 9.3 |
| BOD | mg/l | 2 | - | 2 | - | 4 |
| COD | mg/l | <5 | - | <5 | - | 32 |
| TOC | mg/l | 2 | - | 6 | - | 26 |
| Kjeldahl-N | mg/l | 0.2 | - | 0.4 | - | 0.5 |
| Ammonia-N | mg/l | 0.051 | - | 0.058 | - | 0.050 |
| Nitrite-N | mg/l | 0.002 | - | 0.002 | - | 0.007 |
| Nitrate-N | mg/l | 0.43 | - | 0.51 | - | 0.67 |
| Total Phosphorus | mg/l | 0.014 | - | 0.014 | - | 0.017 |
| Cadmium | mg/l | 0.0002 | - | 0.0002 | - | 0.0011 |

APPENDIX III-1 Continued

| Parameter | Units | Station | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Chromium | mg/l | 0.014 | - | 0.009 | - | 0.026 |
| Iron | mg/l | 0.13 | - | 0.13 | - | 0.13 |
| Lead | mg/l | 0.001 | - | 0.001 | - | 0.001 |
| Manganese | mg/l | 0.016 | - | 0.016 | - | 0.018 |
| Mercury | mg/l | <0.0001 | - | <0.0001 | - | <0.0001 |

APPENDIX III-2

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

16 May 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Specific Conductance | µmhos/cm | 60 | 78 | 65 | 82 | 56 |
| Total Solids | mg/1 | 94 | 70 | 67 | 83 | 81 |
| Total Suspended Solids | mg/1 | 4 | 5 | 4 | 4 | 5 |
| pH | SU | 7.05 | 7.40 | 7.60 | 7.55 | 7.55 |
| Total Alkalinity | mg/1 as $CaCO_3$ | 37 | 36 | 38 | 38 | 37 |
| Chloride | mg/1 | 4.6 | 4.8 | 5.3 | 5.2 | 4.7 |
| Sulfate | mg/1 | 10 | 7 | 7 | 24 | 7 |
| Total Hardness | mg/1 as $CaCO_3$ | 44 | 41 | 40 | 39 | 39 |
| Calcium | mg/1 | 11.3 | 10.2 | 9.7 | 9.4 | 9.3 |
| Magnesium | mg/1 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 |
| Sodium | mg/1 | 2.4 | 2.6 | 2.6 | 2.5 | 2.5 |
| Potassium | mg/1 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Dissolved Oxygen | mg/1 | 9.5 | 9.5 | 9.4 | 9.5 | 9.2 |
| BOD | mg/1 | 2 | 1 | 1 | 2 | 2 |
| COD | mg/1 | 7 | 10 | <5 | 8 | 42 |
| TOC | mg/1 | 2 | 4 | 3 | 4 | 40 |
| Kjeldahl-N | mg/1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.3 |
| Ammonia-N | mg/1 | 0.070 | 0.069 | 0.094 | 0.073 | 0.098 |

APPENDIX III-2 Continued

| Parameter | Units | Station | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Nitrite-N | mg/1 | 0.003 | 0.002 | 0.003 | 0.002 | <0.001 |
| Nitrate-N | mg/1 | 0.50 | 0.52 | 0.48 | 0.41 | 0.47 |
| Total Phosphorus | mg/1 | 0.021 | 0.017 | 0.018 | 0.014 | 0.014 |
| Cadmium | mg/1 | <0.0001 | <0.0001 | 0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/1 | 0.001 | 0.006 | 0.011 | 0.004 | 0.006 |
| Iron | mg/1 | 0.22 | 0.24 | 0.25 | 0.15 | 0.20 |
| Lead | mg/1 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Manganese | mg/1 | 0.032 | 0.033 | 0.035 | 0.031 | 0.035 |
| Mercury | mg/1 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-3

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

17 May 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Specific Conductance | μmhos/cm | 65 | - | 60 | 52 | 52 |
| Total Solids | mg/l | 89 | 69 | 61 | 79 | 67 |
| Total Suspended Solids | mg/l | 2 | 3 | 3 | 1 | 1 |
| pH | SU | 7.65 | 7.60 | 7.65 | 7.60 | 7.65 |
| Total Alkalinity | mg/l as $CaCO_3$ | 42 | 40 | 41 | 39 | 39 |
| Chloride | mg/l | 4.9 | 7.5 | 4.9 | 4.8 | 4.3 |
| Sulfate | mg/l | 30 | 8 | 8 | 12 | 13 |
| Total Hardness | mg/l as $CaCO_3$ | 42 | 39 | 43 | 40 | 38 |
| Calcium | mg/l | 10.2 | 9.7 | 10.6 | 9.5 | 8.8 |
| Magnesium | mg/l | 4.0 | 3.9 | 4.0 | 4.0 | 4.0 |
| Sodium | mg/l | 2.4 | 2.6 | 2.5 | 2.8 | 2.6 |
| Potassium | mg/l | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 |
| Dissolved Oxygen | mg/l | 9.8 | 9.6 | 9.7 | 9.6 | 9.5 |
| BOD | mg/l | 2 | 1 | 3 | 4 | 2 |
| COD | mg/l | <5 | <5 | <5 | 15 | <5 |
| TOC | mg/l | 5 | 5 | 8 | 22 | - |
| Kjeldahl-N | mg/l | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| Ammonia-N | mg/l | 0.089 | 0.073 | 0.089 | 0.080 | 0.071 |

APPENDIX III-3 Continued

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Nitrite-N | mg/1 | <0.001 | <0.001 | <0.001 | 0.002 | 0.005 |
| Nitrate-N | mg/1 | 0.46 | 0.53 | 0.47 | 0.48 | 0.50 |
| Total Phosphorus | mg/1 | 0.008 | 0.010 | 0.014 | 0.011 | 0.012 |
| Cadmium | mg/1 | 0.0001 | 0.0001 | 0.0002 | 0.0002 | 0.0002 |
| Chromium | mg/1 | <0.001 | 0.002 | 0.006 | 0.048 | <0.001 |
| Iron | mg/1 | 0.14 | 0.14 | 0.27 | 0.11 | 0.14 |
| Lead | mg/1 | 0.001 | 0.001 | 0.002 | 0.001 | <0.001 |
| Manganese | mg/1 | 0.020 | 0.020 | 0.025 | 0.020 | 0.025 |
| Mercury | mg/1 | <0.0001 | <0.0001 | 0.0010 | <0.0001 | <0.0001 |

APPENDIX III-4

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

18 May 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Specific Conductance | μmhos/cm | 72 | 60 | 57 | 57 | 57 |
| Total Solids | mg/l | - | 106 | 51 | 91 | 90 |
| Total Suspended Solids | mg/l | 1 | 3 | 1 | 2 | 1 |
| pH | SU | 7.70 | 7.65 | 7.65 | 7.60 | 7.60 |
| Total Alkalinity | mg/l as $CaCO_3$ | 43 | 38 | 39 | 39 | 38 |
| Chloride | mg/l | 6.8 | 4.5 | 6.6 | 6.6 | 6.6 |
| Sulfate | mg/l | 8 | 8 | 7 | 15 | 7 |
| Total Hardness | mg/l as CaCO3 | 38 | 40 | 37 | 40 | 37 |
| Calcium | mg/l | 8.8 | 9.7 | 8.7 | 9.7 | 8.5 |
| Magnesium | mg/l | 3.8 | 3.9 | 3.8 | 3.9 | 3.9 |
| Sodium | mg/l | 2.4 | 2.8 | 2.5 | 2.5 | 2.8 |
| Potassium | mg/l | 1.6 | 1.6 | 1.6 | 1.6 | 1.7 |
| Dissolved Oxygen | mg/l | 9.8 | 9.6 | 9.5 | 9.6 | 9.5 |
| BOD | mg/l | 1 | 1 | 1 | 4 | 1 |
| COD | mg/l | 19 | 1.0 | 9 | 5 | 10 |
| TOC | mg/l | 7 | 2 | 8 | 16 | 20 |
| Kjeldahl-N | mg/l | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| Ammonia-N | mg/l | 0.11 | 0.081 | 0.070 | 0.081 | 0.098 |

APPENDIX III-4 Continued

| Parameters | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Nitrite-N | mg/l | 0.002 | 0.002 | 0.002 | <0.001 | <0.001 |
| Nitrate-N | mg/l | 0.50 | 0.54 | 0.53 | 0.50 | 0.53 |
| Total Phosphorus | mg/l | 0.009 | 0.010 | <0.001 | 0.008 | 0.012 |
| Cadmium | mg/l | 0.0001 | <0.0001 | 0.0002 | 0.0001 | 0.0001 |
| Chromium | mg/l | <0.001 | 0.017 | <0.001 | 0.005 | 0.005 |
| Iron | mg/l | 0.16 | 0.16 | 0.18 | 0.14 | 0.14 |
| Lead | mg/l | 0.001 | <0.001 | 0.001 | 0.001 | 0.001 |
| Manganese | mg/l | 0.022 | 0.022 | 0.024 | 0.022 | 0.023 |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-5

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

20 May 1975

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Specific Conductance | μmhos/cm | 56 | 54 | 70 | 54 | 56 |
| Total Solids | mg/l | 72 | 100 | 105 | 100 | 118 |
| Total Suspended Solids | mg/l | 4 | 3 | 2 | 2 | 2 |
| pH | SU | 6.96 | 6.98 | 7.20 | 6.92 | 6.44 |
| Total Alkalinity | mg/l as $CaCO_3$ | 40 | 39 | 35 | 41 | 40 |
| Chloride | mg/l | 7.7 | 7.3 | 4.5 | 5.6 | 4.8 |
| Sulfate | mg/l | 6 | 25 | 30 | 9 | 8 |
| Total Hardness | mg/l as $CaCO_3$ | 41 | 39 | 41 | 42 | 39 |
| Calcium | mg/l | 9.9 | 9.0 | 9.7 | 10.3 | 9.0 |
| Magnesium | mg/l | 3.9 | 4.1 | 4.0 | 4.1 | 4.0 |
| Sodium | mg/l | 2.4 | 2.5 | 2.5 | 2.4 | 2.5 |
| Potassium | mg/l | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Dissolved Oxygen | mg/l | 9.6 | 9.6 | 9.8 | 9.9 | 9.8 |
| BOD | mg/l | 2 | 2 | 1 | 2 | 2 |
| COD | mg/l | 9 | <5 | <5 | <5 | <5 |
| TOC | mg/l | 2 | 1 | 2 | 1 | 1 |
| Kjeldahl-N | mg/l | 0.2 | 0.1 | 0.2 | 0.2 | 0.1 |
| Ammonia-N | mg/l | 0.062 | 0.080 | 0.074 | 0.089 | 0.076 |

APPENDIX III-5 Continued

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Nitrite-N | mg/l | <0.001 | 0.002 | <0.001 | 0.007 | <0.001 |
| Nitrate-N | mg/l | - | - | - | - | 0.47 |
| Total Phosphorus | mg/l | 0.012 | 0.014 | 0.019 | 0.015 | 0.014 |
| Cadmium | mg/l | 0.0002 | <0.0001 | 0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/l | 0.001 | 0.005 | 0.005 | 0.005 | 0.004 |
| Iron | mg/l | 0.21 | 0.20 | 0.20 | 0.15 | 0.17 |
| Lead | mg/l | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Manganese | mg/l | 0.033 | 0.028 | 0.028 | 0.029 | 0.028 |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-6

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

30 October 1975
(Day)

| Parameter | Units | Stations R1 | R5 | R6 |
|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 50 | 50 | 49 |
| Total Solids | mg/1 | 76 | 80 | 74 |
| Total Suspended Solids | mg/1 | 17 | 14 | 7 |
| pH | SU | 6.70 | 6.70 | 6.60 |
| Total Alkalinity | mg/1 as $CaCO_3$ | 25 | 24 | 25 |
| Chloride | mg/1 | 14.5 | 14.7 | 8.0 |
| Sulfate | mg/1 | 11 | 8 | 9 |
| Total Hardness | mg/1 as $CaCO_3$ | 28 | 29 | 26 |
| Calcium | mg/1 | 6.1 | 6.4 | 5.1 |
| Magnesium | mg/1 | 3.1 | 3.2 | 3.2 |
| Sodium | mg/1 | 3.4 | 3.2 | 3.2 |
| Potassium | mg/1 | 2.4 | 2.5 | 2.4 |
| Dissolved Oxygen | mg/1 | 9.2 | 9.1 | 9.0 |
| BOD | mg/1 | 2 | 2 | 2 |
| COD | mg/1 | <5 | 6 | <5 |
| TOC | mg/1 | 4 | 3 | 8 |
| Kjeldahl-N | mg/1 | 0.4 | 0.4 | 0.4 |
| Ammonia-N | mg/1 | 0.12 | 0.095 | 0.14 |

APPENDIX III-6 Continued

| Parameter | Units | Stations | | |
|---|---|---|---|---|
| | | R1 | R5 | R6 |
| Nitrite-N | mg/l | 0.002 | 0.002 | 0.002 |
| Nitrate-N | mg/l | 0.47 | 0.51 | 0.43 |
| Total Phosphorus | mg/l | 0.011 | 0.011 | 0.011 |
| Cadmium | mg/l | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/l | 0.012 | 0.007 | 0.007 |
| Iron | mg/l | 0.64 | 0.70 | 0.68 |
| Lead | mg/l | 0.002 | 0.003 | 0.003 |
| Manganese | mg/l | 0.074 | 0.095 | 0.114 |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-7

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

30 October 1975
(Night)

| Parameter | Units | Stations | |
|---|---|---|---|
| | | R1 | R4 |
| Specific Conductance | µmhos/cm | 42 | 49 |
| Total Solids | mg/1 | 73 | 74 |
| Total Suspended Solids | mg/1 | 8 | 12 |
| pH | SU | 6.50 | 6.60 |
| Total Alkalinity | mg/1 as $CaCO_3$ | 22 | 24 |
| Chloride | mg/1 | 14.6 | 8.8 |
| Sulfate | mg/1 | 7 | 8 |
| Total Hardness | mg/1 as $CaCO_3$ | 23 | 24 |
| Calcium | mg/1 | 4.5 | 4.9 |
| Magnesium | mg/1 | 29 | 2.9 |
| Sodium | mg/1 | 3.2 | 3.1 |
| Potassium | mg/1 | 2.4 | 2.4 |
| Dissolved Oxygen | mg/1 | 9.1 | 9.0 |
| BOD | mg/1 | 2 | 2 |
| COD | mg/1 | 5 | 6 |
| TOC | mg/1 | 6 | 1 |
| Kjeldahl-N | mg/1 | 0.4 | 0.4 |
| Ammonia-N | mg/1 | 0.097 | 0.11 |

APPENDIX III-7 Continued

| Parameter | Units | Stations | |
|---|---|---|---|
| | | R1 | R4 |
| Nitrite-N | mg/1 | <0.001 | 0.011 |
| Nitrate-N | mg/1 | 0.40 | 0.47 |
| Total Phosphorus | mg/1 | 0.010 | 0.035 |
| Cadmium | mg/1 | <0.0001 | 0.0001 |
| Chromium | mg/1 | 0.008 | 0.007 |
| Iron | mg/1 | 0.32 | 0.61 |
| Lead | mg/1 | 0.002 | 0.003 |
| Manganese | mg/1 | 0.043 | 0.074 |
| Mercury | mg/1 | <0.0001 | <0.0001 |

APPENDIX III-8

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

31 October 1975
*(Day)*

| Parameter | Units | Stations R1 | R5 | R6 |
|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 55 | 55 | 54 |
| Total Solids | mg/l | 79 | 78 | 74 |
| Total Suspended Solids | mg/l | 5 | 13 | 6 |
| pH | SU | 6.80 | 6.65 | 6.70 |
| Total Alkalinity | mg/l as $CaCO_3$ | 26 | 25 | 26 |
| Chloride | mg/l | 10.3 | 14.7 | 11.5 |
| Sulfate | mg/l | 10 | 4 | 11 |
| Total Hardness | mg/l as $CaCO_3$ | 28 | 29 | 27 |
| Calcium | mg/l | 5.9 | 6.3 | 5.4 |
| Magnesium | mg/l | 3.3 | 3.2 | 3.2 |
| Sodium | mg/l | 3.2 | 3.1 | 3.1 |
| Potassium | mg/l | 2.3 | 2.4 | 2.4 |
| Dissolved Oxygen | mg/l | 9.8 | 10.4 | 9.8 |
| BOD | mg/l | 3 | 2 | 2 |
| COD | mg/l | 7 | <5 | <5 |
| TOC | mg/l | 3 | 5 | 12 |
| Kjeldahl-N | mg/l | 0.4 | 0.3 | 0.4 |
| Ammonia-N | mg/l | 0.10 | 0.088 | 0.095 |

APPENDIX III-8 Continued

| Parameter | Units | Stations | | |
|---|---|---|---|---|
| | | R1 | R5 | R6 |
| Nitrite-N | mg/1 | <0.001 | <0.001 | 0.006 |
| Nitrate-N | mg/1 | 0.47 | 0.43 | 0.45 |
| Total Phosphorus | mg/1 | 0.007 | 0.008 | 0.012 |
| Cadmium | mg/1 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/1 | 0.012 | 0.012 | 0.003 |
| Iron | mg/1 | 0.64 | 0.54 | 0.62 |
| Lead | mg/1 | 0.002 | 0.002 | 0.002 |
| Manganese | mg/1 | 0.074 | 0.079 | 0.086 |
| Mercury | mg/1 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-9

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

31 October 1975
(Night)

| Parameter | Units | Stations | |
|---|---|---|---|
| | | R1 | R4 |
| Specific Conductance | µmhos/cm | 61 | 69 |
| Total Solids | mg/l | 72 | 74 |
| Total Suspended Solids | mg/l | 2 | 6 |
| pH | SU | 7.00 | 7.00 |
| Total Alkalinity | mg/l as $CaCO_3$ | 25 | 27 |
| Chloride | mg/l | 11.1 | 13.9 |
| Sulfate | mg/l | 9 | 9 |
| Total Hardness | mg/l as $CaCO_3$ | 25 | 26 |
| Calcium | mg/l | 4.8 | 5.2 |
| Magnesium | mg/l | 3.1 | 3.2 |
| Sodium | mg/l | 3.2 | 3.9 |
| Potassium | mg/l | 2.3 | 2.4 |
| Dissolved Oxygen | mg/l | 9.5 | 9.6 |
| BOD | mg/l | 2 | 2 |
| COD | mg/l | <5 | <5 |
| TOC | mg/l | 3 | - |
| Kjeldahl-N | mg/l | 0.3 | 0.4 |
| Ammonia-N | mg/l | 0.080 | 0.077 |

APPENDIX III-9 Continued

| Parameter | Units | Stations R1 | Stations R4 |
|---|---|---|---|
| Nitrite-N | mg/l | < 0.001 | 0.007 |
| Nitrate-N | mg/l | 0.36 | 0.66 |
| Total Phosphorus | mg/l | 0.010 | 0.035 |
| Cadmium | mg/l | < 0.0001 | < 0.0001 |
| Chromium | mg/l | 0.009 | 0.001 |
| Iron | mg/l | 0.29 | 0.34 |
| Lead | mg/l | 0.002 | 0.002 |
| Manganese | mg/l | 0.036 | 0.048 |
| Mercury | mg/l | < 0.0001 | < 0.0001 |

APPENDIX III-10

RADFORD ARMY AMMUNTION PLANT

Aqueous Phase Chemical Data

New River Stations

1 November 1975
(Day)

| Parameter | Units | Stations | |
|---|---|---|---|
| | | R1 | R5 |
| Specific Conductance | µmhos/cm | 58 | 59 |
| Total Solids | mg/l | 67 | 68 |
| Total Suspended Solids | mg/l | 3 | 6 |
| pH | SU | 7.05 | 7.10 |
| Total Alkalinity | mg/l as $CaCO_3$ | 25 | 25 |
| Chloride | mg/l | 10.6 | 9.8 |
| Sulfate | mg/l | 3 | 5 |
| Total Hardness | mg/l as $CaCO_3$ | 27 | 28 |
| Calcium | mg/l | 5.6 | 6.0 |
| Magnesium | mg/l | 3.1 | 3.1 |
| Sodium | mg/l | 3.2 | 3.2 |
| Potassium | mg/l | 2.3 | 2.4 |
| Dissolved Oxygen | mg/l | 10.2 | 10.0 |
| BOD | mg/l | 2 | 2 |
| COD | mg/l | <5 | 5 |
| TOC | mg/l | 4 | 7 |
| Kjeldahl-N | mg/l | 0.2 | 0.3 |
| Ammonia-N | mg/l | 0.065 | 0.068 |

APPENDIX III-10 Continued

| Parameter | Units | Stations | |
|---|---|---|---|
| | | R1 | R5 |
| Nitrite-N | mg/l | 0.007 | 0.009 |
| Nitrate-N | mg/l | 0.45 | 0.44 |
| Total Phosphorus | mg/l | 0.026 | 0.033 |
| Cadmium | mg/l | <0.0001 | <0.0001 |
| Chromium | mg/l | 0.002 | 0.031 |
| Iron | mg/l | 0.43 | 0.49 |
| Lead | mg/l | 0.001 | 0.002 |
| Manganese | mg/l | 0.044 | 0.058 |
| Mercury | mg/l | <0.0001 | <0.0001 |

APPENDIX III-11

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

1 November 1975
(Night)

| Parameter | Units | Stations | | |
|---|---|---|---|---|
| | | R1 | R4 | R6 |
| Specific Conductance | μmhos/cm | 70 | 72 | 68 |
| Total Solids | mg/1 | 65 | 70 | 69 |
| Total Suspended Solids | mg/1 | 8 | 8 | 6 |
| pH | SU | 7.05 | 7.05 | 7.10 |
| Total Alkalinity | mg/1 as $CaCO_3$ | 26 | 26 | 26 |
| Chloride | mg/1 | 10.9 | 10.2 | 10.4 |
| Sulfate | mg/1 | 5 | 4 | 4 |
| Total Hardness | mg/1 as $CaCO_3$ | 26 | 29 | 30 |
| Calcium | mg/1 | 5.2 | 5.9 | 6.5 |
| Magnesium | mg/1 | 3.3 | 3.4 | 3.3 |
| Sodium | mg/1 | 3.4 | 3.4 | 3.1 |
| Potassium | mg/1 | 2.3 | 2.3 | 2.4 |
| Dissolved Oxygen | mg/1 | 10.0 | 9.9 | 9.9 |
| BOD | mg/1 | 2 | 2 | 2 |
| COD | mg/1 | <5 | <5 | 14 |
| TOC | mg/1 | - | 4 | 8 |
| Kjeldahl-N | mg/1 | 0.3 | 0.3 | 0.3 |
| Ammonia-N | mg/1 | 0.082 | 0.095 | 0.065 |

APPENDIX III-11 Continued

| Parameter | Units | Stations | | |
|---|---|---|---|---|
| | | R1 | R4 | R6 |
| Nitrite-N | mg/l | 0.007 | 0.006 | 0.007 |
| Nitrate-N | mg/l | 0.51 | 0.58 | 0.49 |
| Total Phosphorus | mg/l | 0.029 | 0.030 | 0.035 |
| Cadmium | mg/l | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/l | 0.002 | 0.001 | 0.001 |
| Iron | mg/l | 0.51 | 0.38 | 0.50 |
| Lead | mg/l | 0.002 | 0.002 | 0.002 |
| Manganese | mg/l | 0.042 | 0.047 | 0.059 |
| Mercury | mg/l | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-12

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

3 November 1975
(Night)

| Parameter | Units | Stations R1 | R4 | R6 |
|---|---|---|---|---|
| Specific Conductance | μmhos/cm | 68 | 69 | 69 |
| Total Solids | mg/l | 65 | 55 | 61 |
| Total Suspended Solids | mg/l | 2 | 7 | 8 |
| pH | SU | 6.80 | 6.80 | 6.80 |
| Total Alkalinity | mg/l as $CaCO_3$ | 24 | 25 | 26 |
| Chloride | mg/l | 13.2 | 11.7 | 10.8 |
| Sulfate | mg/l | 4 | 5 | 5 |
| Total Hardness | mg/l as $CaCO_3$ | 24 | 27 | 25 |
| Calcium | mg/l | 4.5 | 5.6 | 5.0 |
| Magnesium | mg/l | 3.1 | 3.1 | 3.1 |
| Sodium | mg/l | 3.4 | 3.9 | 3.5 |
| Potassium | mg/l | 2.3 | 2.3 | 2.3 |
| Dissolved Oxygen | mg/l | 9.2 | 9.1 | 9.2 |
| BOD | mg/l | 2 | 2 | 2 |
| COD | mg/l | <5 | <5 | 14 |
| TOC | mg/l | 8 | 2 | 3 |
| Kjeldahl-N | mg/l | 0.3 | 0.3 | 0.4 |
| Ammonia-N | mg/l | 0.096 | 0.072 | 0.079 |

APPENDIX III-12

| Parameter | Units | Stations | | |
|---|---|---|---|---|
| | | R1 | R4 | R6 |
| Nitrite-N | mg/1 | 0.009 | 0.001 | 0.006 |
| Nitrate-N | mg/1 | 0.40 | 0.77 | 0.56 |
| Total Phosphorus | mg/1 | 0.024 | 0.008 | 0.026 |
| Cadmium | mg/1 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/1 | 0.009 | 0.001 | 0.001 |
| Iron | mg/1 | 0.48 | 0.47 | 0.50 |
| Lead | mg/1 | 0.002 | 0.002 | 0.002 |
| Manganese | mg/1 | 0.046 | 0.048 | 0.064 |
| Mercury | mg/1 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX III-13

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Chemical Data

New River Stations

4 November 1975
(Day)

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R2 | R4 | R5 | R6 |
| Specific Conductance | μmhos/cm | 68 | 65 | 68 | 69 | 59 |
| Total Solids | mg/l | 83 | 90 | 83 | 77 | 81 |
| Total Suspended Solids | mg/l | 10 | 9 | 7 | 8 | 8 |
| pH | SU | 6.85 | 6.85 | 6.90 | 6.95 | 6.90 |
| Total Alkalinity | mg/l as $CaCO_3$ | 27 | 28 | 29 | 28 | 28 |
| Chloride | mg/l | 14.5 | 12.2 | 15.5 | 15.8 | 15.0 |
| Sulfate | mg/l | 7 | 4 | 5 | 5 | 4 |
| Total Hardness | mg/l as $CaCO_3$ | 29 | 30 | 31 | 30 | 29 |
| Calcium | mg/l | 5.9 | 6.6 | 6.8 | 6.4 | 6.0 |
| Magnesium | mg/l | 3.4 | 3.4 | 3.5 | 3.4 | 3.4 |
| Sodium | mg/l | 3.3 | 3.2 | 3.8 | 3.9 | 3.5 |
| Potassium | mg/l | 2.3 | 2.4 | 2.3 | 2.4 | 2.3 |
| Dissolved Oxygen | mg/l | 9.8 | 10.0 | 10.2 | 10.0 | 10.4 |
| BOD | mg/l | 2 | 2 | 2 | 2 | 2 |
| COD | mg/l | 9 | 7 | 7 | 7 | <5 |
| TOC | mg/l | 2 | 3 | 2 | 3 | 4 |
| Kjeldahl-N | mg/l | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 |
| Ammonia-N | mg/l | 0.067 | 0.063 | 0.063 | 0.081 | 0.074 |

APPENDIX III-13 Continued

| Parameter | Units | Stations | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R2 | R4 | R5 | R6 |
| Nitrite-N | mg/l | 0.002 | 0.002 | 0.001 | 0.002 | 0.001 |
| Nitrate-N | mg/l | 0.47 | 0.45 | 0.74 | 0.54 | 0.51 |
| Total Phosphorus | mg/l | 0.010 | 0.009 | 0.011 | 0.008 | 0.010 |
| Cadmium | mg/l | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Chromium | mg/l | 0.007 | 0.002 | 0.002 | 0.001 | 0.003 |
| Iron | mg/l | 0.48 | 0.51 | 0.38 | 0.48 | 0.52 |
| Lead | mg/l | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 |
| Manganese | mg/l | 0.047 | 0.044 | 0.064 | 0.062 | 0.065 |
| Mercury | mg/l | <0.0001 | < 0.0001 | <0.0001 | <0.0001 | <0.0001 |

APPENDIX IV-1

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
15 May 1975

| Parameter | Units | NEW RIVER STATIONS R1 | R4 | R6 |
|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | <0.01 | <0.01 | 0.29 |
| o-nitro-diphenyl amine | mg/l | <0.01 | <0.01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS I18 | I19 | I20 | I22 |
|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 80 | 31 | 39 | 467 |
| o-nitro-dipenyl amine | mg/l | <0.05 | <0.05 | <0.05 | 2.9 |

APPENDIX IV-2

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
16 May 1975

| | | NEW RIVER STATIONS | | | | |
|---|---|---|---|---|---|---|
| Parameter | Units | R1 | R3 | R4 | R5 | R6 |
| Glycerol trinitrate (nitroglycerin) | mg/l | 0.05 | <0.01 | 0.03 | <0.01 | <0.01 |
| o-nitro-dipenyl amine | mg/l | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| | | INDUSTRIAL STATIONS | | | |
|---|---|---|---|---|---|
| Parameter | Units | I18 | I19 | I20 | I22 |
| Glycerol trinitrate (nitroglycerin) | mg/l | 43 | 30 | 120 | 279 |
| o-nitro-dipenyl amine | mg/l | <0.05 | <0.05 | <0.05 | 3.7 |

APPENDIX IV-3

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
17 May 1975

| Parameter | Units | NEW RIVER STATIONS | |
|---|---|---|---|
| | | R3 | R5 |
| Glycerol trinitrate (nitroglycerin) | mg/l | <0.01 | <0.01 |
| *o*-nitro-diphenyl amine | mg/l | <0.01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS | | | |
|---|---|---|---|---|---|
| | | I18 (Prod.) | I18 (Nonprod.) | I22 (Prod.) | I22 (Nonprod.) |
| Glycerol trinitrate (nitroglycerin) | mg/l | 64 | 19 | 637 | 500 |
| *o*-*nitro*-dipenyl amine | mg/l | <0.05 | <0.05 | 3.4 | 2.6 |

APPENDIX IV-4

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
18 May 1975

| Parameter | Units | NEW RIVER STATIONS |
| --- | --- | --- |
| Glycerol trinitrate (nitroglycerin) | mg/l | |
| o-nitro-diphenyl amine | mg/l | |

| Parameter | Units | INDUSTRIAL STATIONS | | | |
| --- | --- | --- | --- | --- | --- |
| | | I19 (Prod.) | I19 (Nonprod.) | I20 (Prod.) | I20 (Nonprod.) |
| Glycerol trinitrate (nitroglycerin) | mg/l | 110 | 50 | 50 | 107 |
| o-nitro-diphenyl amine | mg/l | <.05 | <.05 | <.05 | <.05 |

APPENDIX IV-5

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
20 May 1975

| Parameter | Units | R1 | R3 | R4 | R5 | R6 |
|---|---|---|---|---|---|---|
| | | NEW RIVER STATIONS | | | | |
| Glycerol trinitrate (nitroglycerin) | mg/1 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 |
| o-nitro-dipenyl amine | mg/1 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| Parameter | Units | I21 | I22 |
|---|---|---|---|
| | | INDUSTRIAL STATIONS | |
| Glycerol trinitrate (nitroglycerin) | mg/1 | 101 | 151 |
| o-nitro-dipenyl amine | mg/1 | <0.05 | 14 |

APPENDIX IV-6

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
21 May 1975

| Parameter | Units | R1 | R3 | R4 | R5 | R6 |
|---|---|---|---|---|---|---|
| | | NEW RIVER STATIONS | | | | |
| Glycerol trinitrate (nitroglycerin) | mg/l | 0.03 | 0.01 | <0.01 | <0.01 | <0.01 |
| o-nitro-diphenyl amine | mg/l | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| Parameter | Units | I18 | I19 | I20 |
|---|---|---|---|---|
| | | INDUSTRIAL STATIONS | | |
| Glycerol trinitrate (nitroglycerin) | mg/l | 2 | 106 | 99 |
| o-nitro-diphenyl amine | mg/l | <0.05 | <0.05 | <0.05 |

APPENDIX IV-7

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
22 May 1975

| Parameter | Units | NEW RIVER STATIONS | | | | |
|---|---|---|---|---|---|---|
| | | R1 | R3 | R4 | R5 | R6 |
| Glycerol trinitrate (nitrogylcerin) | mg/l | < 0.01 | < 0.01 | <0.01 | <0.01 | <0.01 |
| o-nitro-diphenyl amine | mg/l | < 0.01 | < 0.01 | < 0.01 | <0.01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS |
|---|---|---|
| Glycerol trinitrate (nitrogylcerin) | mg/l | |
| o-nitro-diphenyl amine | mg/l | |

## APPENDIX IV-8

## RADFORD ARMY AMMUNITION PLANT

### Aqueous Phase Munitions Data
### 30 October 1975

| Parameter | Units | NEW RIVER STATIONS R1 (Day) | R1 (Night) | R4 (Night) | R5 (Day) | R6 (Day) |
|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | <0.002 | <0.002 | - | < 0.002 | 0.003 |
| o-nitro-diphenyl amine | mg/l | <0.01 | <0.01 | - | <0.01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS I18 | I19 | I20 | I21 | I22 |
|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 97 | 1.2 | 239 | 166 | 166 |
| o-nitro-diphenyl amine | mg/l | <0.05 | <0.05 | <0.05 | <0.05 | 1.6 |

APPENDIX IV-9

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
31 October 1975

| | | NEW RIVER STATIONS | | | | |
|---|---|---|---|---|---|---|
| Parameter | Units | R1 (Day) | R1 (Night) | R4 (Night) | R5 (Day) | R6 (Day) |
| Glycerol trinitrate (nitroglycerin) | mg/l | 0.010 | <0.002 | 0.009 | <0.002 | <0.002 |
| o-nitro-diphenyl amine | mg/l | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| | | INDUSTRIAL STATIONS | | | | |
|---|---|---|---|---|---|---|
| Parameter | Units | I18 | I19 | I20 | I21 | I22 |
| Glycerol trinitrate (nitroglycerin) | mg/l | 89 | 8.3 | 143 | 72 | 157 |
| o-nitro-diphenyl amine | mg/l | <0.05 | <0.05 | <0.05 | <0.05 | 1.0 |

APPENDIX IV-10

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
1 November 1975

| Parameter | Units | NEW RIVER STATIONS | | | | |
|---|---|---|---|---|---|---|
| | | R1 (Day) | R1 (Night) | R4 (Night) | R5 (Day) | R6 (Night) |
| Glycerol trinitrate (nitroglycerin) | mg/l | <0.002 | <0.002 | <0.002 | 0.007 | <0.002 |
| o-nitro-diphenyl amine | mg/l | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS | | | | |
|---|---|---|---|---|---|---|
| | | I18 | I19 | I20 | I21 | I22 |
| Glycerol trinitrate (nitroglycerin) | mg/l | 103 | 8.8 | 146 | 16 | 306 |
| o-nitro-diphenyl amine | mg/l | <0.05 | <0.05 | <0.05 | <0.05 | 2.7 |

APPENDIX IV-11

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
3 November 1975

| Parameter | Units | NEW RIVER STATIONS R1 (Night) | R4 (Night) | R6 (Night) |
|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | < 0.002 | <0.002 | <0.006 |
| o-nitro-diphenyl amine | mg/l | <0,01 | <0,01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS I18 | I19 | I20 |
|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 75 | 139 | 66 |
| o-nitro-diphenyl amine | mg/l | <0.05 | <0.05 | <0.05 |

APPENDIX IV-12

RADFORD ARMY AMMUNITION PLANT

Aqueous Phase Munitions Data
4 November 1975

| Parameter | Units | NEW RIVER STATIONS R1 (Day) | R2 (Day) | R4 (Day) | R5 (Day) | R6 (Day) |
|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | <0.002 | <0.002 | 0.020 | 0.010 | <0.002 |
| o-nitro-diphenyl amine | mg/l | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

| Parameter | Units | INDUSTRIAL STATIONS I18 | I19 | I20 | I21 | I22 |
|---|---|---|---|---|---|---|
| Glycerol trinitrate (nitroglycerin) | mg/l | 126 | 262 | 47 | 97 | 258 |
| o-nitro-diphenyl amine | mg/l | <0.05 | <0.05 | <0.05 | <0.05 | 1.7 |

APPENDIX V-1

RADFORD ARMY AMMUNITION PLANT
Sediment Description, New River Stations
May 21, 23, 1975

| Sampling | Sampling Device | Sediment Depth | Color | Fraction <841μm | Description |
|---|---|---|---|---|---|
| R1-A | Corer | 0-10 cm | Brown | 0.1% | Sand |
| R1-B | Corer | 0-8 cm | Brown | 1.2% | Sand |
| R1-C | Corer | 0-7 cm | Brown | 5.0% | Sand with detritus |
| R3-A | Corer | 0-10 cm | Brown | 1.2% | Fine sand with detrius |
| | Corer | 10-20 cm | Brown | 4.4% | Fine sand with detrius |
| R3-B | Corer | 0-10 cm | Brown | 0.1% | Fine sand with detrius |
| | Corer | 10-20 cm | Brown | 9.1% | Fine sand |
| R3-C | Corer | 0-7 cm | Brown | 0.8% | Sand |
| R4-A | Corer | 0-10 cm | Brown | 0.1% | Sand with detritus |
| | Corer | 10-20 cm | Brown | 0.9% | Sand and clay |
| R4-B | Corer | 0-10 cm | Brown | 0.5% | Sand |
| R4-C | Corer | 0-10 cm | Brown | 0.1% | Sand |
| R5-A | Corer | 0-9 cm | Dark Brown | 2.5% | Sand with detritus |
| R5-B | Corer | 0-7 cm | Red-Brown | 0.1% | Clay with detritus and sand |
| R5-C | Corer | 0-9 cm | Brown | 9.1% | Sand and clay |

APPENDIX V-1 Continued

| Samples | Sampling Device | Sediment Depth | Color | Fraction <841 μm | Description |
|---|---|---|---|---|---|
| R6-A | Corer | 0-10 cm | Brown | 9.9% | Sand with detritus |
| | Corer | 10-20 cm | Brown | 13.1% | Sand with detritus and small stones |
| R6-B | Corer | 0-10 cm | Brown | 18.9% | Sand with detritus |
| R6-C | Corer | 0-10 cm | Brown | 12.9% | Sand with small stones and detritus |
| | Corer | 10-17 cm | Brown | 5.7% | Sand with detritus |

APPENDIX V-2

RADFORD ARMY AMMUNITION PLANT
Sediment Description, New River Stations

4 November, 1975

| Samples | Sampling Device | Sediment Depth | Color | Fraction <841 µm | Description |
|---|---|---|---|---|---|
| R1-A | Corer | 0-10 cm | Light brown | 12.1% | Sand, and stones |
| | Corer | 10-20 cm | Light brown | 1.1% | Sand |
| R1-B | Corer | 0-10 cm | Brown | 4.6% | Silt with detritus |
| | Corer | 10-20 cm | Brown | 4.4% | Silt with detritus |
| | Corer | 20-26 cm | Brown | 0.7% | Silt |
| R6-A | Corer | 0-10 cm | Brown | 18.4% | Top 7 cm sand; bottom 3 cm silt and detritus |
| | Corer | 10-15 cm | Dark brown | 3.8% | Silt, sand, and detritus |
| R6-B | Corer | 0-10 cm | Brown | 4.2% | Sand, silt, and detritus |
| | Corer | 10-20cm | Brown | 4.0% | Silt with detritus |
| R6-C | Corer | 0-10 cm | Brown | 12.8% | Sand, silt and detritus |
| | Corer | 10-13 cm | Brown | 27.0% | Silt with detritus |
| R18-A | Corer | 0-10 cm | Brown | 27.6% | Sand with detritus and clay |
| R18-B | Corer | 0-10 cm | Brown | 15.3% | Silt with detritus |
| R18-C | Corer | 0-10 cm | Brown | 9.8% | Silt with detritus |
| | Corer | 10-16 cm | Brown | 20.0% | Sand, silt and detritus |
| R19-A | Corer | 0-10 cm | Gray | 3.4% | Silt |
| | Corer | 10-20 cm | Gray | 3.3% | Silt |

APPENDIX V-2 Continued

| Samples | Sampling Device | Sediment Depth | Color | Fraction <841 μm | Description |
|---|---|---|---|---|---|
| R19-B | Corer | 0-10 cm | Brown | 13.7% | Sand with stones |
| R19-C | Corer | 0-10 cm | Brown | 3.0% | Silt, sand, and detritus |
| | Corer | 10-16 cm | Brown | 1.6% | Silt with detritus |
| R20-A | Corer | 0-10 cm | Brown | 0.0% | Fine sand |
| R20-B | Corer | 0-10 cm | Gray | 0.7% | Silt |
| | Corer | 10-20 cm | Gray | 0.0% | Silt |
| R20-C | Corer | 0-10 cm | Brown | 3.8% | Clay with sand and gravel |
| | Corer | 10-20 cm | Brown | 31.8% | Clay with sand and gravel |
| | Corer | 20-27 cm | Brown and Black | 59.3% | Detritus with sand |
| R22-A | Corer | 0-11 cm | Brown | 58.6% | Coarse sand, 7 large rocks |
| R22-B | Corer | 0-10 cm | Brown | 0.6% | Sand, silt with leaves |
| R22-C | Corer | 0-11 cm | Brown | 6.2% | Clay |

## APPENDIX VI

Taxonomic Keys Used for the Identification of Diatom and Non-diatom Algae


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Appendix VII

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of
Periphyton Diatoms Collected from Five Replicate
Artificial Substrates in the New River, Virginia
During May - June, 1975

| | Station R-1 | | | | | | Station R-2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| Achnanthes lanceolata (Breb.) Grun. var. lanceolata | | | | | | | 9 | 3 | | | | 0.47 |
| A. lanceolata var. dubia Grun. | | | | | | | | | | 1 | | 0.03 |
| A. linearis var. pusilla Grun. | 132 | 137 | 153 | 142 | 68 | 25.63 | 139 | 38 | 13 | 12 | 57 | 10.36 |
| A. minutissima Kuetz. var. minutissima | 70 | 84 | 67 | 93 | 87 | 16.25 | 21 | 10 | 5 | 5 | 10 | 2.04 |
| A. subhudsonis var. kraeuselli Choln. | | | 33 | 29 | | 2.51 | | 3 | | 1 | | 0.16 |
| Amphora ovalis var. pediculus Kuetz. | | | | | | | 1 | | | | | 0.03 |
| A. sp. | | | | | | | | | | | | |
| Asterionella formosa Hass. var. formosa | 1 | 2 | 2 | 1 | 3 | 0.36 | 8 | 2 | | | 2 | 0.48 |
| Cocconeis placentula Ehr. var. placentula | 12 | 1 | 1 | 3 | 1 | 0.73 | 5 | 1 | | | 5 | 0.44 |
| C. placentula var. euglypta (Ehr.) Cl. | 194 | 222 | 198 | 156 | 241 | 40.98 | 259 | 416 | 453 | 444 | 391 | 78.49 |
| C. placentula var. lineata (Ehr.) V.H. | 50 | 9 | 15 | 15 | 30 | 4.82 | 33 | 21 | 14 | 30 | 15 | 4.52 |
| Cyclotella comta (Ehr.) Kuetz. var. comta | | | | 1 | | 0.04 | | | | | | |
| C. pseudostelligera Hust. var. pseudostelligera | 2 | | 1 | 1 | | 0.16 | 1 | 1 | | | | 0.08 |
| C. stelligera Cl. & Grun. var. stelligera | | | | | | | | | | | | |
| Cymbella affinis Kuetz. var. affinis | | | | | | | | | | | | |

APPENDIX VII Continued

| Replicates | Station R-1 1 | 2 | 3 | 4 | 5 | % | Station R-2 1 | 2 | 3 | 4 | 5 | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C. sinuata Gregory var. sinuata | 4 | 6 | 3 | 4 | | 0.69 | 1 | | | | 7 | 0.32 |
| C. ventricosa Kuetz. var. ventricosa | | | | | 4 | 0.16 | 1 | | | | | 0.04 |
| Diatoma vulgare Bory var. vulgare | | | | | | | | | | | 1 | 0.04 |
| Fragilaria construens (Ehr.) Grun. var. construens | | | | | | | | | | | | |
| F. crotonensis Kitton var. crotonensis | | | | | | | 3 | | | | | 0.12 |
| Gomphonema angustatum var. productum Grun. | | | | | 1 | 0.04 | | | | | | |
| G. apicatum Ehr. var. apicatum | | | | | | | | | | | | |
| G. gracile var. dichotomum A. Mayer | | | | | | | | | | | | |
| G. olivaceum var. olivaceum f. minutula A. Mayer | | | | | 1 | 0.04 | | | | | | |
| G. olivaceum var. tenellum (Kuetz.) Cl. | 4 | | | | 1 | 0.20 | | | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | 3 | 1 | 0.16 | | | | | | |
| G. parvulum var. aequalis A. Mayer | | | | | 4 | 0.16 | | | | | | |
| G. parvulum var. exilissima Grun. | 4 | 1 | | | | 0.20 | | | | | | |
| G. parvulum var. micropus (Kuetz.) Cl. | 1 | 30 | 21 | | 3 | 2.23 | | | 13 | 2 | | 0.60 |
| G. parvulum var. subelliptica Cleve | | | | 15 | | 0.61 | | | | | | |
| G. (girdle view) | 20 | | | | 18 | 1.54 | 10 | 2 | | 2 | 9 | 0.92 |
| Melosira granulata (E.) Ralfs var. granulata | | | | | | | 2 | 1 | | | | 0.12 |
| M. italica (Ehr.) Kuetz. var. | | | | | | | | | | | | |
| M. varians C. A. Ag. var. varians | | | | | | | | | | | | |
| Navicula accomoda Hust. var. accomoda | 1 | | | | | 0.04 | | | | | | |
| N. cryptocephala Kuetz. var. cryptocephala | 1 | | | | | 0.04 | | 1 | | | | 0.04 |
| N. cryptocephala f. minuta Boye P. | | 1 | | | | 0.04 | | | | | | |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | | | | | | 1 | | | | | 0.04 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | | | | | | | | | | | |
| N. minima Grun. var. minima | 2 | | 1 | 1 | 3 | 0.28 | 1 | | | | 3 | 0.16 |

| | Station R-1 | | | | | | Station R-2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| N. pseudoreinhardtii Patr. var. pseudoreinhardtii | | | | | 1 | 0.04 | | | | | | |
| N. radiosa var. parva Wallace | | | | | | | | | | | | |
| N. salinarum var. intermedia (Grun.) Cl. | | | | | 2 | 0.08 | | | | | | |
| N. tripunctata (O. F. Muell.) Bory var. tripunctata | | | | | | | | | 1 | | | 0.04 |
| N. (girdle view) 16 - 20 $\mu$ long, 12 - 14 striae/10 | | | | | | | 1 | | | 1 | | 0.08 |
| N. sp. No. 5: 30 $\mu$ long, 6 $\mu$ wide; 14 - 16 striae/ 10 c.f. N. odiosa Wallace var. odiosa | | | | 1 | | 0.04 | | | | | | |
| Nitzschia amphibia Grun. var. amphibia | | | | | | | | | | | | |
| N. capitellata Hust. var. capitellata | | | | | | | | | | | | |
| N. filiformis (W. Smith) Hust. var. filiformis | | | | | 1 | 0.04 | | | | | | |
| N. fonticola Grun. var. fonticola | | | | 2 | 1 | 0.12 | | | | | | |
| N. frustulum (Kuetz.) Grun. var. frustulum | 1 | 5 | 1 | | 3 | 0.40 | 2 | | 1 | | | 0.12 |
| N. kuetzingiana Hilse var. kuetzingiana | | | | | 19 | 0.77 | | | | | | |
| N. palea (Kuetz.) W. Smith var. palea | 1 | | 1 | | | 0.08 | | | | | | |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | | | | | | | | | | | |
| Surirella delicatissima Lewis var. delicatisima | | | | | | | | 1 | | | | 0.04 |
| Synedra pulchella Ralfs ex. Kuetz. var. pulchella | | | | | | | | | | | | |
| S. pulchella var. lacerata Hust. | | | | | | | | | | | | |
| S. rumpens var. meneghiniana Grun. | | | | | | | | | | | | |
| S. socia Wallace var. socia | | 3 | 3 | 1 | 8 | 0.61 | 5 | | | | | 0.20 |
| Total Number of Taxa | 17 | 12 | 14 | 16 | 21 | | 19 | 13 | 7 | 9 | 10 | |
| Total Number of Individuals | 500 | 501 | 500 | 468 | 498 | | 503 | 500 | 500 | 498 | 500 | |

Appendix VII

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of
Periphyton Diatoms Collected from Five Replicate
Artificial Substrates in the New River, Virginia
During May - June, 1975

| | Station R-3 | | | | | | Station R-4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| Achnanthes lanceolata (Breb.) Grun. var. lanceolata | | | | | | | 21 | | 27 | | 44 | 3.68 |
| A. lanceolata var. dubia Grun. | | | | | | | | 13 | | | | 0.52 |
| A. linearis var. pusilla Grun. | 38 | 29 | 15 | 61 | 5 | 5.91 | 100 | 49 | 79 | 134 | 112 | 18.98 |
| A. minutissima Kuetz. var. minutissima | 9 | 10 | 3 | 9 | | 1.24 | 114 | 56 | 107 | 221 | 179 | 27.11 |
| A. subhudsonis var. kraeuselli Choln. | | | 1 | 2 | | 0.12 | | | 27 | | | 1.08 |
| Amphora ovalis var. pediculus Kuetz. | | | | | | | 1 | | | 1 | | 0.08 |
| A. sp. | | | | | | | | | | | 1 | 0.04 |
| Asterionella formosa Hass. var. formosa | 1 | | | | 1 | 0.08 | 1 | 12 | | 2 | 3 | 0.72 |
| Cocconeis placentula Ehr. var. placentula | 5 | | | 1 | | 0.24 | 2 | 10 | 1 | | | 0.52 |
| C. placentula var. euglypta (Ehr.) Cl. | 403 | 443 | 446 | 406 | 462 | 86.23 | 164 | 268 | 166 | 61 | 65 | 28.99 |
| C. placentula var. lineata (Ehr.) V.H. | 30 | 13 | 32 | 23 | 29 | 5.07 | 21 | 33 | 19 | 10 | 6 | 3.56 |
| Cyclotella comta (Ehr.) Kuetz. var. comta | | | | | | | | 1 | | 1 | | 0.08 |
| C. pseudostelligera Hust. var. pseudostelligera | 2 | 1 | | | | 0.12 | 1 | 1 | | | | 0.08 |
| C. stelligera Cl. & Grun. var. stelligera | | | | | | | | 1 | | | | 0.04 |
| Cymbella affinis Kuetz. var. affinis | | | | | | | | | | 8 | | 0.32 |
| C. sinuata Gregory var. sinuata | 4 | 1 | | 2 | | 0.28 | 9 | 2 | 6 | 2 | 5 | 0.96 |

APPENDIX VII Cont.

| | Station R-3 | | | | | | Station R-4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| C. ventricosa Kuetz. var. ventricosa | 2 | | | | | 0.08 | 1 | 1 | 3 | 3 | 1 | 0.36 |
| Diatoma vulgare Bory var. vulgare | | | | | | | | | | | | |
| Fragilaria construens (Ehr.) Grun. var. construens | | | | | | | | 1 | | | | 0.04 |
| F. crotonensis Kitton var. crotonensis | | | | | | | | | | | | |
| Gomphonema angustatum var. productum Grun. | | | | | | | | | | 4 | | 0.16 |
| G. apicatum Ehr. var. apicatum | | | | | | | | | | | | |
| G. gracile var. dichotomum A. Mayer | | | | | | | 1 | | | | | 0.04 |
| G. olivaceum var. olivaceum f. minutula A. Mayer | | | | | | | | | 25 | | | 1.00 |
| G. olivaceum var. tenellum (Kuetz.) Cl. | | 3 | | | | 0.12 | 17 | | 19 | | 1 | 14.82 |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | | | | | | 10 | | 34 | 1.76 |
| G. parvulum var. aequalis A. Mayer | | | | | | | | | | | | |
| G. parvulum var. exilissima Grun. | | | | | | | | | | | | |
| G. parvulum var. micropus (Kuetz.) Cl. | | | | | | | 20 | 33 | | 46 | 41 | 5.61 |
| G. parvulum var. subelliptica Cleve | | | | | | | | | | | | |
| G. (girdle view) | | | 2 | 1 | 2 | 0.20 | | | | | | |
| Melosira granulata (E.) Ralfs var. granulata | | | | | | | 1 | | | | | 0.04 |
| M. italica (Ehr.) Kuetz. var. | | | | | | | | | | | | |
| M. varians C. A. Ag. var. varians | | | | | | | | 1 | | | | 0.04 |
| Navicula accomoda Hust. var. accomoda | | | | | | | 1 | | | | | 0.04 |
| N. cryptocephala Kuetz. var. cryptocephala | | | | | | | 1 | | | | 1 | 0.08 |
| N. cryptocephala f. minuta Boye P. | | | | | | | 1 | | | | 1 | 0.08 |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | | | | | | | | | | | |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | | | | | | | 2 | | | | 0.08 |

| | Station R-3 | | | | | | Station R-4 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| N. minima Grun. var. minima | 3 | | | | | 0.12 | | 4 | 2 | 1 | 1 | 0.32 |
| N. pseudoreinhardtii Patr. var. pseudoreinhardtii | | | | | | | | | | | | |
| N. radiosa var. parva Wallace | | | | | | | | | | 1 | | 0.04 |
| N. salinarum var. intermedia (Grun.) Cl. | | | | | | | | | | 1 | | 0.04 |
| N. tripunctata (O. F. Muell.) Bory var. tripunctata | | | | | | | | | | | 1 | 0.04 |
| N. (girdle view) 16 - 20μ long, 12 - 14 striae/10 | 3 | | | | | 0.12 | 13 | | | | | 0.52 |
| N. sp. No. 5: 30μ long, 6μ wide; 14 - 16 striae/ 10 c.f. N. odiosa Wallace var. odiosa | | | | | | | | | | | | |
| Nitzschia amphibia Grun. var. amphibia | | | | | 1 | 0.04 | | | | | | |
| N. capitellata Hust. var. capitellata | | | | | | | | 1 | | | | 0.04 |
| N. filiformis (W. Smith) Hust. var. filiformis | | | | | | | | | | | | |
| N. fonticola Grun. var. fonticola | | | | | | | | | | | 1 | 0.04 |
| N. frustulum (Kuetz.) Grun. var. frustulum | | | | | | | 4 | 7 | 4 | | 1 | 0.64 |
| N. kuetzingiana Hilse var. kuetzingiana | | | | | | | | | 2 | 2 | | 0.16 |
| N. palea (Kuetz.) W. Smith var. palea | | | | | | | | | | 2 | 1 | 0.12 |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | | | | | | 1 | | | | | 0.04 |
| Surirella delicatisima Lewis var. delicatissima | | | | | | | | | | | | |
| Synedra pulchella Ralfs ex. Kuetz. var. pulchella | | | | | | | 1 | | | | | 0.04 |
| S. pulchella var. lacerata Hust. | | | | | | | | | 2 | | | 0.08 |
| S. rumpens var. meneghiniana Grun. | | | | | | | | 2 | | | | 0.08 |
| S. socia Wallace var. socia | | | 1 | | | 0.04 | 1 | 1 | 1 | | 1 | 0.16 |
| Total Number of Taxa | 11 | 7 | 7 | 8 | 6 | | 23 | 22 | 17 | 17 | 20 | |
| Total Number of Individuals | 500 | 500 | 500 | 505 | 500 | | 497 | 500 | 500 | 500 | 500 | |

Appendix VII

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of
Periphyton Diatoms Collected from Five Replicate
Artificial Substrates in the New River, Virginia
During May - June, 1975

| | Station R-5 | | | | | | Station R-6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| Achnanthes lanceolata (Breb.) Grun. var. lanceolata | | | NO SAMPLE | | | | | | | | | |
| A. lanceolata var. dubia Grun. | | | | | | | | | | | | |
| A. linearis var. pusilla Grun. | | | | | | | 47 | 128 | 171 | 210 | 184 | 29.65 |
| A. minutissima Kuetz. var. minutissima | | | | | | | 36 | 72 | 56 | 71 | 35 | 10.82 |
| A. subhudsonis var. kraeuselii Choln. | | | | | | | | 18 | | | 19 | 1.48 |
| Amphora ovalis var. pediculus Kuetz. | | | | | | | | 2 | | | | 0.08 |
| A. sp. | | | | | | | | | | | | |
| Asterionella formosa Hass. var. formosa | | | | | | | | 4 | | 3 | 2 | 0.36 |
| Cocconeis placentula Ehr. var. placentula | | | | | | | | 1 | | 1 | | 0.08 |
| C. placentula var. euglypta (Ehr.) Cl. | | | | | | | 345 | 218 | 237 | 138 | 195 | 45.39 |
| C. placentula var. lineata (Ehr.) V.H. | | | | | | | 45 | 27 | 10 | 10 | 11 | 4.13 |
| Cyclotella comta (Ehr.) Kuetz. var. comta | | | | | | | | | | | | |
| C. pseudostelligera Hust. var. pseudostelligera | | | | | | | | | | | | |
| C. stelligera Cl. & Grun. var. stelligera | | | | | | | | | | | | |

APPENDIX VII Cont.

| | Station R-5 | | | | | | Station R-6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| Cymbella affinis Kuetz. var. affinis | | | NO SAMPLE | | | | | | | | | |
| C. sinuata Gregory var. sinuata | | | | | | | 1 | 4 | 2 | 8 | 11 | 1.04 |
| C. ventricosa Kuetz. var. ventricosa | | | | | | | | | | | | |
| Diatoma vulgare Bory var. vulgare | | | | | | | | | | | | |
| Fragilaria construens (Ehr.) Grun. var. construens | | | | | | | | | | | | |
| F. crotonensis Kitton var. crotonensis | | | | | | | | | | | | |
| Gomphonema angustatum var. productum Grun. | | | | | | | | | | | | |
| G. apicatum Ehr. var. apicatum | | | | | | | | | | | | |
| G. gracile var. dichotomum A. Mayer | | | | | | | | | | | | |
| G. olivaceum var. olivaceum f. minutula A. Mayer | | | | | | | | | | 3 | | 0.12 |
| G. olivaceum var. tenellum (Kuetz.) Cl. | | | | | | | 2 | | | | | 0.08 |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | | | | | | | | | |
| G. parvulum var. aequalis A. Mayer | | | | | | | | | | | | |
| G. parvulum var. exilissima Grun. | | | | | | | | | | | | |
| G. parvulum var. micropus (Kuetz.) Cl. | | | | | | | 17 | 23 | 3 | | | 1.72 |
| G. parvulum var. subelliptica Cleve | | | | | | | | | | | | |
| G. (girdle view) | | | | | | | | | 16 | 54 | 37 | 4.29 |
| Melosira granulata (E.) Ralfs var. granulata | | | | | | | | | | | | |
| M. italica (Ehr.) Kuetz. var. | | | | | | | 4 | | | | | 0.16 |
| M. varians C. A. Ag. var. varians | | | | | | | | | | | | |
| Navicula accomoda Hust. var. accomoda | | | | | | | | | | | | |

APPENDIX VII Cont.

| | Station R-5 | | | | | | Station R-6 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | % | 1 | 2 | 3 | 4 | 5 | % |
| N. cryptocephala Kuetz. var. cyptocephala | | | NO SAMPLE | | | | | | | | | |
| N. cryptocephala f. minuta Boye P. | | | | | | | | | | | | |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | | | | | | | | | | | |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | | | | | | | | | | | |
| N. minima Grun. var. minima | | | | | | | | | | | | |
| N. pseudoreinhardtii Patr. var. pseudoreinhardtii | | | | | | | | | | | | |
| N. radiosa var. parva Wallace | | | | | | | | | | | 1 | 0.04 |
| N. salinarum var. intermedia (Grun.) Cl. | | | | | | | | | | | | |
| N. tripunctata (O. F. Muell.) Bory var. tripunctata | | | | | | | 1 | | | | | 0.04 |
| N. (girdle view) 16-20 long, 12-14 striae/10 | | | | | | | | | | | | |
| N. sp. No. 5: 30 μ long, 6 μ wide; 14-16 striae/ 10 c.f. N. odiosa Wallace var. odiosa | | | | | | | | | | | | |
| Nitzschia amphibia Grun. var. amphibia | | | | | | | | | | | | |
| N. capitellata Hust. var. capitellata | | | | | | | | | | | | |
| N. filiformis (W. Smith) Hust. var. filiformis | | | | | | | | | | | | |
| N. fonticola Grun. var. fonticola | | | | | | | | | | | | |
| N. frustulum (Kuetz.) Grun. var. frustulum | | | | | | | 1 | 1 | 1 | 1 | 1 | 0.20 |
| N. kuetzingiana Hilse var. kuetzingiana | | | | | | | | | | | | |
| N. palea (Kuetz.) W. Smith var. palea | | | | | | | | | | | | |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | | | | | | | | 1 | 1 | | 0.08 |
| Surirella delicatissima Lewis var. delicatissima | | | | | | | | | | | | |
| Synedra pulchella Ralfs ex. Kuetz. var. pulchella | | | | | | | | | | | | |
| S. pulchella var. lacerata Hust. | | | | | | | | | | | | |
| S. rumpens var. meneghiniana Grun. | | | | | | | | | | | | |
| S. socia Wallace var. socia | | | | | | | 1 | 1 | | | | 0.08 |
| Total number of taxa | | | | | | | 11 | 13 | 10 | 11 | 11 | |
| Total number of individuals | | | | | | | 500 | 500 | 499 | 500 | 497 | |

APPENDIX VIII

Percentage of Occurrence of Non-diatom Algae Compared to the Diatom Group. Collected from Three Replicate Artificial Substrates, New River, Virginia. May-June 1975.

Station R-1

| | Replicates 1 | 2 | 3 | Percent Dominance |
|---|---|---|---|---|
| **Chlorophyta:** | | | | |
| Chlamydomonas globosa Snow | | | | |
| Microspora tumidula Hazen | | | | |
| Oocystis pusilla Hansgirg | | | | |
| O. submarina Lagerheim | | | | |
| Protoderma viride Kuetzing | 15 | 13 | 19 | 2.81 |
| Scenedesmus quadricauda (Turp.) de Breb. | | | | |
| Stigeoclonium nanum Kuetzing | | | | |
| S. tenue (C. A. Ag.) Kuetz. | 3 | 3 | 5 | 0. 0.66 |
| **Cyanophyta:** | | | | |
| Anabaena felisii (Menegh.) Bornet & Flahault | | | | |
| Aphanocapsa elachista West & West | 2 | 0 | 5 | 0.42 |
| Aphanothece clathrata G. S. West | 4 | 6 | 1 | 0.66 |
| A. microscopica Naegeli | 2 | 5 | 6 | 0.78 |
| Chamaesiphon incrustans Grunow | 16 | 29 | 18 | 3.77 |
| Chroococcus dispersus (Keissl.) Lemm. | 58 | 59 | 63 | 10.76 |
| C. minor (Kuetz.) Naegeli | 37 | 36 | 35 | 6.46 |
| Lyngbya diguetii Gomont | | | | |
| L. limnetica Lemm. | 2 | | 1 | 0.18 |
| L. nordgaardii Wille | | | | |
| Microcystis aeruginosa Kuetz. | 3 | 3 | 3 | 0.54 |
| Oscillatoria amphibia C. A. Agardh | 81 | 82 | 74 | 14.17 |
| Phormidium minnesotense (Tilden) Drouet | | | | |
| P. mucicola Naumann & Huber-Pestalozzi | | | | |
| P. tenue (Menegh.) Gomont | | 1 | 1 | 0.12 |
| **Bacillariophyta:** | | | | |
| Centrics | 7 | 3 | 5 | 0.90 |
| Pennates | 290 | 361 | 316 | 57.8 |
| Total Number of Taxa | 13 | 12 | 14 | 14 |
| Total Number of Individuals | 520 | 601 | 552 | 1673 |
| Species Richness $\frac{S-1}{\ln N}$ | | | | 1.75 |

APPENDIX VIII

Percentage of Occurrence of Non-diatom Algae Compared to the Diatom Group. Collected from Three Replicate Artificial Substrates, New River, Virginia. May-June 1975.

| | Station R-2 Replicates 1 | 2 | 3 | Percent Dominance |
|---|---|---|---|---|
| Chlorophyta: | | | | |
| Chlamydomonas globosa Snow | | | | |
| Microspora tumidula Hazen | | | | |
| Oocystis pusilla Hansgirg | 1 | 6 | 4 | 0.50 |
| O. submarina Lagerheim | | | | |
| Protoderma viride Kuetzing | | | | |
| Scenedesmus quadricauda (Turp.) de Breb. | | | | |
| Stigeoclonium nanum Kuetzing | 10 | 13 | 7 | 1.36 |
| S. tenue (C. A. Ag.) Kuetz. | | | | |
| Cyanophyta: | | | | |
| Anabaena felisii (Menegh.) Bornet & Flahault | | | | |
| Aphanocapsa elachista West & West | | | | |
| Aphanothece clathrata G. S. West | | | | |
| A. microscopica Naegeli | | | | |
| Chamaesiphon incrustans Grunow | 14 | 14 | 14 | 1.91 |
| Chroococcus dispersus (Keissl.) Lemm. | 87 | 58 | 79 | 10.20 |
| C. minor (Kuetz.) Naegeli | 24 | 40 | 29 | 4.23 |
| Lyngbya diguetii Gomont | 14 | 10 | 13 | 1.68 |
| L. limnetica Lemm. | | | | |
| L. nordgaardii Wille | | | | |
| Microcystis aeruginosa Kuetz. | | | | |
| Oscillatoria amphibia C. A. Agardh | 41 | 32 | 34 | 4.87 |
| Phormidium minnesotense (Tilden) Drouet | 1 | | | 0.05 |
| P. mucicola Naumann & Huber-Pestalozzi | 5 | 6 | 8 | 0.86 |
| P. tenue (Menegh.) Gomont | | | | |
| Bacillariophyta: | | | | |
| Centrics | 5 | 5 | 1 | 0.50 |
| Pennates | 637 | 469 | 516 | 73.83 |
| Total Number of Taxa | 11 | 10 | 10 | 11 |
| Total Number of Individuals | 839 | 653 | 705 | 2197 |
| Species Richness $\frac{S-1}{\ln N}$ | | | | 1.30 |

## APPENDIX VIII

Percentage of Occurrence of Non-diatom Algae Compared to the Diatom Group. Collected from Three Replicate Artificial Substrates, New River, Virginia. May-June 1975.

| | Station - R-3 | | | |
|---|---|---|---|---|
| | Replicates | | | |
| | 1 | 2 | 3 | Percent Dominance |
| Chlorophyta: | | | | |
| *Chlamydomonas globosa* Snow | | 2 | | 0.06 |
| *Microspora tumidula* Hazen | | | | |
| *Oocystis pusilla* Hansgirg | 3 | 8 | 4 | 0.48 |
| *O. submarina* Lagerheim | | | | |
| *Protoderma viride* Kuetzing | 10 | 16 | 15 | 1.32 |
| *Scenedesmus quadricauda* (Turp.) de Breb. | | | | |
| *Stigeoclonium nanum* Kuetzing | | | | |
| *S. tenue* (C. A. Ag.) Kuetz. | | | | |
| Cyanophyta: | | | | |
| *Anabaena felisii* (Menegh.) Bornet & Flahault | | | | |
| *Aphanocapsa elachista* West & West | | | | |
| *Aphanothece clathrata* G. S. West | | | | |
| *A. microscopica* Naegeli | 3 | 5 | 3 | 0.35 |
| *Chamaesiphon incrustans* Grunow | 22 | 21 | 22 | 2.09 |
| *Chroococcus dispersus* (Keissl.) Lemm. | 76 | 78 | 79 | 7.50 |
| *C. minor* (Kuetz.) Naegeli | 31 | 41 | 30 | 3.28 |
| *Lyngbya diguetii* Gomont | 16 | 14 | 19 | 1.58 |
| *L. limnetica* Lemm. | | | | |
| *L. nordgaardii* Wille | | | | |
| *Microcystis aeruginosa* Kuetz. | 3 | 2 | 3 | 0.26 |
| *Oscillatoria amphibia* C. A. Agardh | 22 | 14 | 17 | 1.71 |
| *Phormidium minnesotense* (Tilden) Drouet | | | | |
| *P. mucicola* Naumann & Huber-Pestalozzi | 13 | 15 | 10 | 1.22 |
| *P. tenue* (Menegh.) Gomont | 1 | 2 | 0 | 0.10 |
| Bacillariophyta: | | | | |
| Centrics | 3 | 2 | 3 | 0.26 |
| Pennates | 1342 | 623 | 513 | 79.78 |
| Total Number of Taxa | 13 | 14 | 12 | 14 |
| Total Number of Individuals | 1545 | 843 | 718 | 3106 |
| Species Richness $\frac{S-1}{\ln N}$ | | | | 1.62 |

## APPENDIX VIII

Percentage of Occurrence of Non-diatom Algae Compared to the Diatom Group. Collected from Three Replicate Artificial Substrates, New River, Virginia. May-June 1975.

| | Station R-4 Replicates 1 | 2 | 3 | Percent Dominance |
|---|---|---|---|---|
| Chlorophyta: | | | | |
| Chlamydomonas globosa Snow | | | | |
| Microspora tumidula Hazen | | | | |
| Oocystis pusilla Hansgirg | | | | |
| O. submarina Lagerheim | 8 | 12 | 11 | 0.014 |
| Protoderma viride Kuetzing | 6 | 3 | 7 | 0.007 |
| Scenedesmus quadricauda (Turp.) de Breb. | 1 | 3 | 2 | 0.003 |
| Stigeoclonium nanum Kuetzing | 2 | 3 | 4 | 0.004 |
| S. tenue (C. A. Ag.) Kuetz. | | | | |
| Cyanophyta: | | | | |
| Anabaena felisii (Menegh.) Bornet & Flahault | | 2 | 2 | 0.002 |
| Aphanocapsa elachista West & West | | | | |
| Aphanothece clathrata G. S. West | | | | |
| A. microscopica Naegeli | 7 | 4 | 6 | 0.01 |
| Chamaesiphon incrustans Grunow | 8 | 12 | 6 | 0.01 |
| Chroococcus dispersus (Keissl.) Lemm. | 18 | 18 | 26 | 0.03 |
| C. minor (Kuetz.) Naegeli | 11 | 31 | 31 | 0.03 |
| Lyngbya diguetii Gomont | 39 | 28 | 26 | 0.04 |
| L. limnetica Lemm. | | | | |
| L. nordgaardii Wille | | | | |
| Microcystis aeruginosa Kuetz. | 15 | 9 | 13 | 0.017 |
| Oscillatoria amphibia C. A. Agardh | 109 | 108 | 106 | 0.15 |
| Phormidium minnesotense (Tilden) Drouet | | | | |
| P. mucicola Naumann & Huber-Pestalozzi | | | | |
| P. tenue (Menegh.) Gomont | | | | |
| Bacillariophyta: | | | | |
| Centrics | 9 | 17 | 11 | 0.02 |
| Pennates | 495 | 513 | 453 | 0.66 |
| Total Number of Taxa | 13 | 14 | 14 | 14 |
| Total Number of Individuals | 728 | 763 | 704 | 2195 |
| Species Richness $\frac{S-1}{\ln N}$ | | | | 1.68 |

APPENDIX VIII

Percentage of Occurrence of Non-diatom Algae Compared to the Diatom Group. Collected from Three Replicate Artificial Substrates, New River, Virginia. May-June 1975.

| | Station R-6 Replicates | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | Percent Dominance |
| **Chlorophyta:** | | | | |
| Chlamydomonas globosa Snow | | | | |
| Microspora tumidula Hazen | 1 | 3 | 2 | 0.32 |
| Cocystis pusilla Hansgirg | | | | |
| O. submarina Lagerheim | | | | |
| Protoderma viride Kuetzing | 7 | 3 | 9 | 1.00 |
| Scenedesmus quadricauda (Turp.) de Breb. | | | | |
| Stigeoclonium nanum Kuetzing | 2 | 2 | 1 | 0.26 |
| S. tenue (C. A. Ag.) Kuetz. | | | | |
| **Cyanophyta:** | | | | |
| Anabaena felisii (Menegh.) Bornet & Flahault | | | | |
| Aphanocapsa elachista West & West | | | | |
| Aphanothece clathrata G. S. West | | | | |
| A. microscopica Naegeli | | 5 | 8 | 0.69 |
| Chamaesiphon incrustans Grunow | 5 | 7 | 3 | 0.79 |
| Chroococcus dispersus (Keissl.) Lemm. | 31 | 36 | 31 | 5.19 |
| C. minor (Kuetz.) Naegeli | 3 | | | 0.16 |
| Lyngbya diguetii Gomont | | | | |
| L. limnetica Lemm. | | | | |
| L. nordgaardii Wille | 5 | 5 | 2 | 0.63 |
| Microcystis aeruginosa Kuetz. | 8 | 14 | 14 | 1.90 |
| Oscillatoria amphibia C. A. Agardh | 127 | 122 | 116 | 19.31 |
| Phormidium minnesotense (Tilden) Drouet | | | | |
| P. mucicola Naumann & Huber-Pestalozzi | | 5 | 2 | 0.37 |
| P. tenue (Menegh.) Gomont | | | | |
| **Bacillariophyta:** | | | | |
| Centrics | 8 | 11 | 8 | 1.43 |
| Pennates | 430 | 433 | 421 | 67.94 |
| Total Number of Taxa | 11 | 12 | 12 | 13 |
| Total Number of Individuals | 627 | 646 | 617 | 1890 |
| Species Richness $\frac{S-1}{\ln N}$ | | | | 1.59 |

Appendix IX

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of
Periphyton Diatoms Collected from Three Natural Substrates
in the New River, Virgina
During June, 1975

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Achnanthes acares Hohn & Hellerm. sp. nov. var. acares | | 82 | | 8.20 | | | | |
| A. clevei Grun. var. clevei | | 11 | | 1.10 | | | | |
| A. clevei var. rostrata Hust. | | | | | | | | |
| A. exigua var. heterovalva Krasske | | 16 | | 1.60 | | | | |
| A. hauckiana Grun. var. hauckiana | | | | | | | | |
| A. lanceolata (Breb.) Grun. var. lanceolata | | 10 | | 1.00 | | | | |
| A. lanceolata var. dubia Grun. | 3 | | | 0.30 | | 1 | | 0.10 |
| A. linearis var. pusilla Grun. | 28 | 49 | | 7.70 | 52 | 7 | | 5.85 |
| A. minutissima Kuetz. var. minutissima | 14 | 16 | | 3.00 | 20 | 4 | | 2.38 |
| A. subhudsonis var. kraeuselli Choln. | | | | | | 1 | | 0.10 |
| | | | | | | | | |
| Amphora ovalis Kuetz. var. ovalis | | | | | | | | |
| A. ovalis var. pediculus Kuetz. | | | | | | | | |
| A. perpusilla Grun. var. perpusilla | | 2 | | 0.20 | | | | |
| A. veneta Kuetz var. veneta | | | | | | 2 | | 0.20 |
| A. sp. | 1 | | | 0.10 | 3 | | | 0.30 |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Asterionella formosa Hass. var. formosa | | 5 | | 0.50 | 6 | 5 | | 1.10 |
| A. formosa var. gracillima (Hantz.) Grun. | 7 | | | 0.70 | 13 | | | 1.29 |
| Caloneis bacillum (Grun.) Cl. var. bacillum | | | | | | | | |
| Cocconeis pediculus Ehr. var. pediculus | | | | | | | | |
| C. placentula var. euglypta (Ehr.) Cl. | 2 | 17 | | 1.90 | 6 | 3 | | 0.89 |
| C. placentula var. lineata (Ehr.) V. H. | | | | | | | | |
| Cyclotella comta (Ehr.) Kuetz. var. comta | | | | | | 5 | | 0.50 |
| C. meneghiniana Kuetz. var. meneghiniana | 1 | | | 0.10 | | | | |
| C. operculata (Ag.) Kuetz. var. operculata | | | | | | | | |
| C. pseudostelligera Hust. var. pseudostelligera | 7 | 8 | | 1.50 | 11 | 2 | | 1.29 |
| C. stelligera Cl & Grun. var. stelligera | 2 | 2 | | 0.40 | | | | |
| C. sp. (girdle view). | | | | | | | | |
| Cymbella affinis Kuetz. var. affinis | | | | | 2 | 2 | | 0.40 |
| C. perpusilla A. Cleve var. perpusilla | | | | | | | | |
| C. prostata (Berkeley) Cleve var. prostata | | | | | | | | |
| C. sinuata Gregory var. sinuata | | | | | 2 | | | 0.20 |
| C. tumida (Breb.) V. H. var. tumida | | | | | | | | |
| C. turgida (Gregory) Cl. var. turgida | 1 | | | 0.10 | | | | |
| C. ventricosa Kuetz. var. ventricosa | 7 | 4 | | 1.10 | 13 | 2 | | 1.49 |
| Diatoma vulgare Bory var. vulgare | | 4 | | 0.40 | 8 | 6 | | 1.39 |
| D. vulgare var. breve Grun. | | | | | 1 | | | 0.10 |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Fragilaria capucina var. mesolepta Rabh. | | 1 | | 0.10 | | | | |
| F. construens (Ehr.) Grun. var. construens | | | | | 3 | | | 0.30 |
| F. construens var. binodis (Ehr.) Grun. | | | | | | | | |
| F. construens var. pumila Grun. | 1 | | | 0.10 | | | | |
| F. crotonensis Kitton var. crotonensis | | | | | | 1 | | 0.10 |
| F. leptostauron var. dubia (Grun.) Hust. | | 1 | | 0.10 | | | | |
| F. pinnata Ehr. var. pinnata | 3 | | | 0.30 | | | | |
| F. pinnata var. lancettula (Schaum.) Hust. | | | | | | | | |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 2 | | | 0.20 | | | | |
| F. (girdle view) | | | | | | | | |
| | | | | | | | | |
| Frustulia rhomboides (Ehr.) DeT. var. rhomboides | | | | | | | | |
| F. rhomboides var. amphipleuroides (Grun.) Cl. | | 1 | | 0.10 | | | | |
| F. rhomboides var. viridula (Breb) Cl. | | 1 | | 0.10 | | | | |
| F. vulgaris (Thwaites) DeT. var. vulgaris | | | | | | | | |
| F. sp. (girdle view) | | | | | 1 | | | 0.10 |
| | | | | | | | | |
| Gomphonema angustatum (Kuetz.) Rabh. var. angustatum | 4 | | | 0.40 | | | | |
| G. angustatum f. brevis A. Mayer | | | | | | | | |
| G. angustatum var. productum Grun. | 1 | | | 0.10 | 4 | | | 0.40 |
| G. angustatum var. productum f. typica Grun. | | | | | | | | |
| G. constrictum var. capitata (Ehr.) Cleve | | | | | | | | |
| G. constrictum var. capitata f. italicum A. Mayer | | | | | | | | |
| G. constrictum var. | | 1 | | 0.10 | | | | |
| G. gracile var. dichotomum A. Mayer | | | | | | | | |
| G. gracile var. lanceolata (Kuetz.) Cleve | | | | | | | | |
| G. olivaceum (Lyngb.)Kuetz. var. olivaceum | 1 | | | 0.10 | 6 | | | 0.59 |
| G. olivaceum var. olivaceum f. minutula A. Mayer | | 2 | | 0.20 | | 1 | | 0.10 |
| G. olivaceum var. olivaceum f. typica A. Mayer | | | | | | | | |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| G. olivaceum var. tenellum (Kuetz.) Cl. | | 1 | | 0.10 | | | | |
| G. olivaceum var. vulgaris f. typica A. Mayer | | | | | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | | 1 | | | 0.10 |
| G. parvulum var. exilissima Grun. | | | | | | | | |
| G. parvulum var. micropus (Kuetz.) Cl. | | 1 | | 0.10 | | | | |
| G. parvulum var. subelliptica Cleve | | | | | | | | |
| | | | | | | | | |
| Gyrosigma acuminatum (Kuetz.) Rabh. var. acuminatum | | | | | 1 | | | 0.10 |
| G. obtusatum (Sulliv. & Wormley) var. obtusatum | | | | | | | | |
| G. spencerii (Quek.) Griff. & Henfr. var. spencerii | | 2 | | 0.20 | | 1 | | 0.10 |
| G. spencerii var. curvula (Grun.) Reim. comb. nov. | | 2 | | 0.20 | | | | |
| | | | | | | | | |
| Melosira distans (Ehr.) Kuetz. var. distans | | | | | | | | |
| M. granulata (E.) Ralfs var. granulata | | | | | | | | |
| M. islandica O. Muell. var. | | | | | 2 | | | 0.20 |
| M. italica (Ehr.) Kuetz. var. | | | | | | | | |
| M. varians C. A. Ag. var. varians | | 6 | | 0.60 | | | | |
| M. (valve view) | | | | | | | | |
| | | | | | | | | |
| Meridion circulare (Grev.) Ag. var. circulare | | 2 | | 0.20 | | | | |
| M. circulare var. constrictum (Ralfs) V.H. | 1 | | | 0.10 | | | | |
| | | | | | | | | |
| Navicula absoluta Hust. nov. sp. var. absoluta | | 1 | | 0.10 | | | | |
| N. accomoda Hust. var. accomoda | | 10 | | 1.00 | 2 | | | 0.20 |
| N. aikenensis Patr. var. aikenensis | 1 | | | 0.10 | | | | |
| N. arvensis Hust. var. arvensis | 2 | 1 | | 0.30 | | | | |
| N. capitata Ehr. var. capitata | | | | | | | | |
| N. cryptocephala Kuetz. var. cryptocephala | 6 | | | 0.60 | 2 | 6 | | 0.79 |
| N. cryptocephala f. minuta Boye P. | | | | | | | | |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | 7 | | 0.70 | | 4 | | 0.40 |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. decussis ostr. var. decussis | | | | | | | | |
| N. elginensis var. neglecta (Krasske) Patr. comb. nov. | | | | | | 1 | | 0.10 |
| N. exigua (Gregory) O. Mueller var. exigua | | | | | 2 | | | 0.20 |
| N. frugalis Hust. var. frugalis | | 1 | | 0.10 | | 6 | | 0.59 |
| N. graciloides A. Mayer var. graciloides | | | | | 1 | | | 0.10 |
| N. gregaria Donk. var. gregaria | | 4 | | 0.40 | | 12 | | 1.19 |
| N. habergii Hust. var. hambergii | | | | | 1 | 1 | | 0.20 |
| N. hustedtii Krasske var. hustedtii | | | | | | | | |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | 2 | | 0.20 | 12 | 2 | | 1.39 |
| N. laterostrata Hust. var. laterostrata | | | | | 2 | | | 0.20 |
| N. menisculus var. upsaliensis (Grun.) Grun. | | | | | 1 | | | 0.10 |
| N. minima Grun. var. minima | 11 | 35 | | 4.60 | 14 | 9 | | 2.28 |
| N. minuscula Grun. var. minuscula | | | | | | | | |
| N. muraloides Hust. nov. sp. var. muraloides | 4 | | | 0.40 | 1 | | | 0.10 |
| N. mutica Kuetz. var. mutica | | | | | | 13 | | 1.29 |
| N. mutica var. stigma Patr. | | | | | | | | |
| N. mutica var. tropica Hust. | 91 | | | 9.10 | 17 | 3 | | 1.98 |
| N. mutica var. undulata (Hilse) Grun. | 129 | 1 | | 13.00 | 47 | 157 | | 20.24 |
| N. odiosa Wallace var. odiosa | | | | | | 1 | | 0.10 |
| N. pelliculosa (Breb. ex. Kuetz.) Hilse var. pelliculosa | | | | | | | | |
| N. pseudoreinhardtii Patr. var. pseudoreinhardtii | | | | | | | | |
| N. pupula Kuetz. var. pupula | | | | | | | | |
| N. pupula var. capitata Skv. & Meyer | | | | | | | | |
| N. pupula var. rectangularis (Greg.) Grun. | | | | | | | | |
| N. radiosa var. parva Wallace | | 1 | | 0.10 | 1 | | | 0.10 |
| N. radiosa var. tenella (Breb. ex. Kuetz.) Grun. | | 3 | | 0.30 | 2 | | | 0.20 |
| N. rhynchocephala Kuetz. var. rhychocephala | | | | | | 4 | | 0.40 |
| N. rhynchocephala var. germanii (Wallace) Patr. comb. nov. | | | | | 3 | | | 0.30 |
| N. rotunda Hust. var. rotunda | | | | | | | | |
| N. sabiniana Patr. var. sabiniana | | | | | | | | |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. salinarum var. intermedia (Grun.) Cl. | 19 | 5 | | 2.40 | 35 | 2 | | 3.67 |
| N. schroeteri var. escambia Patr. | | | | | 1 | | | 0.10 |
| N. secreta var. apiculata Patr. | 6 | | | 0.60 | 37 | | | 3.67 |
| N. sorella Hohn & Hellerm. var. sorella | | | | | | | | |
| N. symmetrica Patr. var. symmetrica | 1 | 1 | | 0.20 | | | | |
| N. tripunctata (O. F. Muell.) Bory var. tripunctata | 2 | 11 | | 1.30 | 1 | 1 | | 0.20 |
| N. tripunctata var. schizomeroides (V.H.) Patr. | 1 | 1 | | 0.20 | | | | |
| N. (girdle view) 16-20μ long, 12-14 striae/10 | | | | | | | | |
| N. (girdle view) 45μ long; 10 striae/10 | | 2 | | 0.20 | | | | |
| N. sp. No. 50μ long, 8.5μ wide; 12 striae/10 c.f. N. symmetrica Patr. var. symmetrica | | | | | | | | |
| N. sp. No. 3: 17-18μ long, 5μ wide; 20 striae/10 c.f. N. menisculus var. upsaliensis (Grun.) Grun. | | | | | 1 | | | 0.10 |
| N. sp. No. 4: 10.5μ long, 5μ wide; 14 striae/10 | | | | | | | | |
| N. sp. No. 5: 10μ long, 6μ wide; 14-16 striae/10 c.f. N. odiosa Wallace var. odiosa | | | | | | | | |
| Neidium dubium (Ehr.) Cl. var. dubium | | | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | 1 | | | 0.10 | 5 | | | 0.50 |
| N. amphibia Grun. var. amphibia | | 6 | | 0.60 | | 2 | | 0.20 |
| N. bacata Hust. var. bacata | | | | | | | | |
| N. biacrula Hohn & Hellerm. sp. nov. var. biacrula | | | | | | | | |
| N. capitellata Hust. var. capitellata | 3 | | | 0.30 | 2 | 9 | | 1.09 |
| N. clausii Hantzsch var. clausii | | | | | | 29 | | 2.88 |
| N. communis Rabh. var. communis | | | | | | 4 | | 0.40 |
| N. dissipata (Kuetz.) Grun. var. dissipata | 10 | 30 | | 4.00 | 14 | 14 | | 2.78 |
| N. elliptica Hust. var. elliptica | | | | | | | | |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. filiformis (W. Smith) Hust. var. filiformis | | 1 | | 0.10 | | | | |
| N. fonticola Grun. var. fonticola | 3 | | | 0.30 | 23 | | | 2.28 |
| N. frustulum (Kuetz.) Grun. var. frustulum | 20 | 15 | | 3.50 | 6 | 24 | | 2.98 |
| N. gracilis Hantzsch var. gracilis | | | | | 1 | 1 | | 0.20 |
| N. kittonii H. L. Smith var. kittonii | | | | | 1 | | | 0.10 |
| N. kuetzingiana Hilse var. kuetzingiana | | | | | | | | |
| N. lacunarum Hust. var. lacunarum | | | | | 1 | | | 0.10 |
| N. legleri Hust. var. legleri | | | | | | 1 | | 0.10 |
| N. linearis W. Smith var. linearis | | 3 | | 0.30 | 3 | 1 | | 0.40 |
| N. microcephala Grun. var. microcephala | | | | | | 1 | | 0.10 |
| N. palea (Kuetz.) W. Smith var. palea | 20 | 9 | | 2.90 | 58 | 89 | | 14.58 |
| N. paleacea Grun. var. paleacea | | | | | | | | |
| N. paleaeformis Hust. nov. sp. var. paleaeformis | | 1 | | 0.10 | | | | |
| N. parvula Lewis var. parvula | 66 | | | 6.60 | 9 | 35 | | 4.36 |
| N. recta Hantzsch var. recta | | | | | | 1 | | 0.10 |
| N. romana Grun. var. romana | | | | | | 12 | | 1.19 |
| N. sigma (Kuetz.) W. Smith var. sigma | | | | | | | | |
| N. sigmoidea (Ehr.) W. Smith var. sigmoidea | | | | | | | | |
| N. sinuata (W. Smith) Grun. var. sinuata | | | | | 1 | | | 0.10 |
| N. sinuata var. tabellariae Grun. | | 1 | | 0.10 | | | | |
| Pinnularia braunii var. amphicephala (A. Mayer) Hust. | | | | | | 1 | | 0.10 |
| P. sp. No. 1: 20μ long, 5μ wide; striae fine, 24/10 | | 2 | | 0.20 | | | | |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | 57 | | 5.70 | 4 | 1 | | 0.50 |
| Stauroneis ignorata Hust. var. ignorata | | | | | | | | |
| S. kriegeri Patr. var. kriegeri | | | | | | | | |
| Stephanodiscus astraea (Ehr.) Grun. var. astraea | | | | | 4 | | | 0.40 |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| S. astraea var. minutula (Kuetz.) Grun. | | | | | | | | |
| S. invisitatus Hohn & Hellerm. sp. nov. var. invisitatus | | 2 | | 0.20 | 3 | | | 0.30 |
| S. niagarae Ehr. var. niagarae | | | | | | | | |
| Surirella angusta Kuetz. var. angusta | 1 | | | 0.10 | 1 | 3 | | 0.40 |
| S. delicatissima Lewis var. delicatissima | 1 | | | 0.10 | | | | |
| S. linearis W. Sm. var. linearis | | | | | | | | |
| S. linearis var. constricta (E.) Grun. | | | | | | | | |
| S. ovata Kuetz. var. ovata | 1 | 1 | | 0.20 | 2 | 2 | | 0.40 |
| S. ovata var. pinnata W. Smith | | | | | | | | |
| Synedra acus Kuetz. var. acus | | 2 | | 0.20 | | | | |
| S. delicatissima W. Sm. var. delicatisima | | | | | | | | |
| S. goulardi Breb. var. goulardi | | | | | | | | |
| S. incisa Boyer var. incisa | | 2 | | 0.20 | | | | |
| S. parasitica (W. Sm.) Hust. var. parasitica | | | | | 2 | | | 0.20 |
| S. pulchella Ralfs ex. Kuetz. var. pulchella | | 1 | | 0.10 | | | | |
| S. pulchella var. lacerata Hust. | | | | | | | | |
| S. pulchella var. lanceolata O'Meara | | | | | | | | |
| S. radians Kuetz. var. radians | | | | | 1 | | | 0.10 |
| S. rumpens Kuetz. var. rumpens | | | | | | | | |
| S. rumpens var. familiaris (Kuetz.) Hust. | 3 | | | 0.30 | 4 | | | 0.40 |
| S. rumpens var. meneghiniana Grun. | 4 | | | 0.40 | 3 | | | 0.30 |
| S. rumpens var. scotia Grun. | 4 | | | 0.40 | 7 | | | 0.69 |
| S. socia Wallace var. socia | | 18 | | 1.80 | 1 | 8 | | 0.89 |
| S. ulna (Nitz.) Ehr. var. ulna | 2 | 9 | | 1.10 | 4 | 5 | | 0.89 |
| S. ulna var. contracta ostr. | | 5 | | 0.50 | | 1 | | 0.10 |
| S. ulna var. ramesi (Herib.) Hust. | 2 | | | 0.20 | 2 | | | 0.20 |
| S. sp. | | | | | | | | |

APPENDIX IX Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| _Tabellaria_ _fenestrata_ (Lyngb.) Kuetz. var. _fenestrata_ | | | | | | | | |
| Total Number of Taxa | 45 | 60 | | | 64 | 50 | | |
| Total Number of Individuals | 500 | 500 | | | 500 | 508 | | |

Appendix IX

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of
Periphyton Diatoms Collected from Three Natural Substrates
in the New River, Virgina
During June, 1975

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Achnanthes acares Hohn & Hellerm. sp. nov. var. acares | | 7 | | 0.70 | | | | |
| A. clevei Grun. var. clevei | | | | | | | | |
| A. clevei var. rostrata Hust. | | | | | 3 | | | 0.30 |
| A. exigua var. heterovalva Krasske | | | | | | | | |
| A. hauckiana Grun. var. hauckiana | | | | | 3 | | | 0.30 |
| A. lanceolata (Breb.) Grun. var. lanceolata | | | | | 5 | 5 | | 0.99 |
| A. lanceolata var. dubia Grun. | 1 | 8 | | 0.91 | 3 | 7 | | 0.99 |
| A. linearis var. pusilla Grun. | 68 | 100 | | 17.00 | 59 | 72 | | 13.02 |
| A. minutissima Kuetz. var. minutissima | 27 | 48 | | 7.59 | 16 | 16 | | 3.18 |
| A. subhudsonis var. kraeuselli Choln. | | | | | | 25 | | 2.48 |
| Amphora ovalis Kuetz. var. ovalis | | 1 | | 0.10 | | | | |
| A. ovalis var. pediculus Kuetz. | | | | | 1 | | | 0.10 |
| A. perpusilla Grun. var. perpusilla | | 1 | | 0.10 | | | | |
| A. veneta Kuetz var. veneta | | | | | | | | |
| A. sp. | | | | | 1 | | | 0.10 |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Asterionella formosa Hass. var. formosa | 8 | 4 | | 1.21 | 8 | 1 | | 0.89 |
| A. formosa var. gracillima (Hantz.) Grun. | | | | | | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | | 1 | | 0.10 | | | | |
| Cocconeis pediculus Ehr. var. pediculus | | | | | | 8 | | 0.79 |
| C. placentula var. euglypta (Ehr.) Cl. | 8 | 17 | | 2.53 | 9 | 6 | | 1.49 |
| C. placentula var. lineata (Ehr.) V. H. | | | | | | | | |
| Cyclotella comta (Ehr.) Kuetz. var. comta | | 5 | | 0.51 | | 2 | | 0.20 |
| C. meneghiniana Kuetz. var. meneghiniana | | | | | 1 | | | 0.10 |
| C. operculata (Ag.) Kuetz. var. operculata | | | | | | | | |
| C. pseudostelligera Hust. var. pseudostelligera | 11 | 2 | | 1.32 | 9 | 4 | | 1.29 |
| C. stelligera Cl & Grun. var. stelligera | 1 | 2 | | 0.30 | | 1 | | 0.10 |
| C. sp. (girdle view). | | | | | | 2 | | 0.20 |
| Cymbella affinis Kuetz. var. affinis | | | | | | 2 | | 0.20 |
| C. perpusilla A. Cleve var. perpusilla | | | | | | | | |
| C. prostata (Berkeley) Cleve var. prostata | | | | | | | | |
| C. sinuata Gregory var. sinuata | 1 | 2 | | 0.30 | 2 | 3 | | 0.50 |
| C. tumida (Breb.) V. H. var. tumida | | 2 | | 0.20 | | 1 | | 0.10 |
| C. turgida (Gregory) Cl. var. turgida | | | | | | | | |
| C. ventricosa Kuetz. var. ventricosa | 10 | 18 | | 2.83 | 17 | 32 | | 4.87 |
| Diatoma vulgare Bory var. vulgare | | 6 | | 0.61 | 11 | 10 | | 2.09 |
| D. vulgare var. breve Grun. | | | | | | | | |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rrock | sediment | % |
| Fragilaria capucina var. mesolepta Rabh. | | | | | | 1 | | 0.10 |
| F. construens (Ehr.) Grun. var. construens | | | | | | | | |
| F. construens var. binodis (Ehr.) Grun. | | 9 | | 0.91 | 1 | | | 0.10 |
| F. construens var. pumila Grun. | | | | | | | | |
| F. crotonensis Kitton var. crotonensis | | | | | 1 | 1 | | 0.20 |
| F. leptostauron var. dubia (Grun.) Hust. | | | | | | | | |
| F. pinnata Ehr. var. pinnata | | 1 | | 0.10 | | | | |
| F. pinnata var. lancettula (Schaum.) Hust. | 1 | | | 0.10 | | | | |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 2 | | | 0.20 | | | | |
| F. (girdle view) | | | | | | 2 | | 0.20 |
| Frustulia rhomboides (Ehr.) DeT. var. rhomboides | | | | | | 1 | | 0.10 |
| F. rhomboides var. amphipleuroides (Grun.) Cl. | | 1 | | 0.10 | | | | |
| F. rhomboides var. viridula (Breb) Cl. | 2 | | | 0.20 | | | | |
| F. vulgaris (Thwaites) DeT. var. vulgaris | | | | | | | | |
| F. sp. (girdle view) | | | | | | | | |
| Gomphonema angustatum (Kuetz.) Rabh. var. angustatum | | | | | | | | |
| G. angustatum f. brevis A. Mayer | | | | | | | | |
| G. angustatum var. productum Grun. | | | | | | | | |
| G. angustatum var. productum f. typica Grun. | | | | | 1 | | | 0.10 |
| G. constrictum var. capitata (Ehr.) Cleve | | | | | 1 | | | 0.10 |
| G. constrictum var. capitata f. italicum A. Mayer | | 7 | | 0.71 | | | | |
| G. constrictum var. | | | | | | | | |
| G. gracile var. dichotomum A. Mayer | | | | | | | | |
| G. gracile var. lanceolata (Kuetz.) Cleve | | 1 | | 0.10 | | | | |
| G. olivaceum (Lyngb.)Kuetz. var. olivaceum | 1 | | | 0.10 | | | | |
| G. olivaceum var. olivaceum f. minutula A. Mayer | 2 | 7 | | 0.91 | 1 | 2 | | 0.30 |
| G. olivaceum var. olivaceum f. typica A. Mayer | | | | | 1 | | | 0.10 |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| G. olivaceum var. tenellum (Kuetz.) Cl. | 2 | 6 | | 0.81 | 2 | 1 | | 0.30 |
| G. olivaceum var. vulgaris f. typica A. Mayer | | | | | 3 | | | 0.30 |
| G. parvulum (Kuetz.) Grun. var. parvulum | 1 | | | 0.10 | 1 | | | 0.10 |
| G. parvulum var. exilissima Grun. | | | | | 2 | 2 | | 0.40 |
| G. parvulum var. micropus (Kuetz.) Cl. | 1 | 3 | | 0.40 | | 2 | | 0.20 |
| G. parvulum var. subelliptica Cleve | | | | | | | | |
| | | | | | | | | |
| Gyrosigma acuminatum (Kuetz.) Rabh. var. acuminatum | | | | | | | | |
| G. obtusatum (Sulliv. & Wormley) var. obtusatum | | | | | | 1 | | 0.10 |
| G. spencerii (Quek.) Griff. & Henfr. var. spencerii | | | | | | | | |
| G. spencerii var. curvula (Grun.) Reim. comb. nov. | | 1 | | 0.10 | 3 | | | 0.30 |
| | | | | | | | | |
| Melosira distans (Ehr.) Kuetz. var. distans | | | | | | | | |
| M. granulata (E.) Ralfs var. granulata | | 4 | | 0.40 | | 2 | | 0.20 |
| M. islandica O. Muell. var. | | | | | | | | |
| M. italica (Ehr.) Kuetz. var. | 5 | | | 0.51 | | | | |
| M. varians C. A. Ag. var. varians | | | | | | 2 | | 0.20 |
| M. (valve view) | | | | | 4 | | | 0.40 |
| | | | | | | | | |
| Meridion circulare (Grev.) Ag. var. circulare | | | | | | | | |
| M. circulare var. constrictum (Ralfs) V.H. | | 1 | | 0.10 | | | | |
| | | | | | | | | |
| Navicula absoluta Hust. nov. sp. var. absoluta | | | | | | | | |
| N. accomoda Hust. var. accomoda | | 3 | | 0.30 | | 9 | | 0.89 |
| N. aikenensis Patr. var. aikenensis | | 1 | | 0.10 | | | | |
| N. arvensis Hust. var. arvensis | | 2 | | 0.20 | 2 | 1 | | 0.30 |
| N. capitata Ehr. var. capitata | | | | | | 2 | | 0.20 |
| N. cryptocephala Kuetz. var. cryptocephala | 20 | 5 | | 2.53 | | 10 | | 0.99 |
| N. cryptocephala f. minuta Boye P. | 1 | | | 0.10 | 3 | | | 0.30 |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | 2 | | 0.20 | 6 | 7 | | 1.29 |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. decussis ostr. var. decussis | | | | | 1 | | | 0.10 |
| N. elginensis var. neglecta (Krasske) Patr. comb. nov. | | | | | | | | |
| N. exigua (Gregory) O. Mueller var. exigua | | | | | | | | |
| N. frugalis Hust. var. frugalis | 2 | 7 | | 0.91 | | 2 | | 0.20 |
| N. graciloides A. Mayer var. graciloides | 1 | | | 0.10 | | | | |
| N. gregaria Donk. var. gregaria | 51 | 21 | | 7.29 | 52 | 23 | | 7.45 |
| N. habergii Hust. var. hambergii | | | | | 1 | | | 0.10 |
| N. hustedtii Krasske var. hustedtii | | | | | 1 | | | 0.10 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | 10 | 9 | | 1.92 | 5 | 9 | | 1.39 |
| N. laterostrata Hust. var. laterostrata | | | | | | | | |
| N. menisculus var. upsaliensis (Grun.) Grun. | | | | | | | | |
| N. minima Grun. var. minima | 19 | 7 | | 2.63 | 7 | 2 | | 0.89 |
| N. minuscula Grun. var. minuscula | 1 | | | 0.10 | | | | |
| N. muraloides Hust. nov. sp. var. muraloides | | | | | | | | |
| N. mutica Kuetz. var. mutica | | | | | 3 | 11 | | 1.39 |
| N. mutica var. stigma Patr. | | | | | | | | |
| N. mutica var. tropica Hust. | 3 | | | 0.30 | 4 | | | 0.40 |
| N. mutica var. undulata (Hilse) Grun. | 1 | 2 | | 0.30 | 9 | 72 | | 8.05 |
| N. odiosa Wallace var. odiosa | | 1 | | 0.10 | | | | |
| N. pelliculosa (Breb. ex. Kuetz.) Hilse var. pelliculosa | 1 | | | 0.10 | | | | |
| N. pseudoreinhardtii Patr. var. pseudoreinhardtii | | | | | | | | |
| N. pupula Kuetz. var. pupula | | | | | | | | |
| N. pupula var. capitata Skv. & Meyer | | | | | | | | |
| N. pupula var. rectangularis (Greg.) Grun. | | | | | | | | |
| N. radiosa var. parva Wallace | | | | | | 1 | | 0.10 |
| N. radiosa var. tenella (Breb. ex. Kuetz.) Grun. | | | | | | | | |
| N. rhynchocephala Kuetz. var. rhychocephala | | 1 | | 0.10 | | | | |
| N. rhynchocephala var. germanii (Wallace) Patr. comb. nov. | | | | | | | | |
| N. rotunda Hust. var. rotunda | | | | | 1 | | | 0.10 |
| N. sabiniana Patr. var. sabiniana | | | | | | 1 | | 0.10 |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. salinarum var. intermedia (Grun.) Cl. | 38 | 6 | | 4.45 | 18 | 16 | | 3.38 |
| N. schroeteri var. escambia Patr. | 1 | | | 0.10 | | | | |
| N. secreta var. apiculata Patr. | 5 | | | 0.51 | | | | |
| N. sorella Hohn & Hellerm. var. sorella | 2 | | | 0.20 | 2 | | | 0.20 |
| N. symmetrica Patr. var. symmetrica | | | | | | | | |
| N. tripunctata ( O. F. Muell.) Bory var. tripunctata | 2 | 8 | | 1.01 | 4 | 8 | | 1.19 |
| N. tripunctata var. schizomeroides (V.H.) Patr. | | | | | | | | |
| N. (girdle view) 16-20μ long, 12-14 striae/10 | | 2 | | 0.20 | | 3 | | 0.30 |
| N. (girdle view) 45μ long; 10 striae/10 | | | | | | | | |
| N. sp. No. 2: 50μ long, 8.5μ wide; 12 striae/10 c.f. N. symmetrica Patr. var. symmetrica | | | | | | | | |
| N. sp. No. 3: 17-18μ long, 5μ wide; 20 striae/10 c.f. N. menisculus var. upsaliensis (Grun.) Grun. | | | | | | | | |
| N. sp. No. 4: 10.5μ long, 5μ wide; 14 striae/10 | 1 | | | 0.10 | | | | |
| N. sp. No. 5: 10μ long, 6μ wide; 14-16 striae/10 c.f. N. odiosa Wallace var. odiosa | 5 | | | 0.51 | | | | |
| Neidium dubium (Ehr.) Cl. var. dubium | | | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | | | | | | | | |
| N. amphibia Grun. var. amphibia | | 2 | | 0.20 | | 2 | | 0.20 |
| N. bacata Hust. var. bacata | | | | | | 1 | | 0.10 |
| N. biacrula Hohn & Hellerm. sp. nov. var. biacrula | 1 | | | 0.10 | | | | |
| N. capitellata Hust. var. capitellata | 4 | | | 0.40 | 5 | 1 | | 0.60 |
| N. clausii Hantzsch var. clausii | | 1 | | 0.10 | | 1 | | 0.10 |
| N. communis Rabh. var. communis | | 1 | | 0.10 | | 1 | | 0.10 |
| N. dissipata (Kuetz.) Grun. var. dissipata | 31 | 16 | | 4.76 | 20 | 10 | | 2.98 |
| N. elliptica Hust. var. elliptica | | | | | | | | |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. filiformis (W. Smith) Hust. var. filiformis | | | | | | | | |
| N. fonticola Grun. var. fonticola | 7 | | | 0.71 | 13 | | | 1.29 |
| N. frustulum (Kuetz.) Grun. var. frustulum | 20 | 10 | | 3.04 | 23 | 3 | | 2.58 |
| N. gracilis Hantzsch var. gracilis | | 1 | | 0.01 | | 3 | | 0.30 |
| N. kittonii H. L. Smith var. kittonii | | | | | | | | |
| N. kuetzingiana Hilse var. kuetzingiana | | | | | | | | |
| N. lacunarum Hust. var. lacunarum | | | | | | | | |
| N. legleri Hust. var. legleri | | | | | | | | |
| N. linearis W. Smith var. linearis | 16 | 5 | | 2.12 | 6 | 6 | | 1.19 |
| N. microcephala Grun. var. microcephala | | | | | | | | |
| N. palea (Kuetz.) W. Smith var. palea | 16 | 1 | | 1.72 | 19 | 4 | | 2.29 |
| N. paleacea Grun. var. paleacea | | | | | | | | |
| N. paleaeformis Hust. nov. sp. var. paleaeformis | | | | | | | | |
| N. parvula Lewis var. parvula | 56 | 37 | | 9.41 | 77 | 40 | | 11.63 |
| N. recta Hantzsch var. recta | | | | | | | | |
| N. romana Grun. var. romana | | | | | | | | |
| N. sigma (Kuetz.) W. Smith var. sigma | | | | | | 1 | | 0.10 |
| N. sigmoidea (Ehr.) W. Smith var. sigmoidea | | | | | 1 | | | 0.10 |
| N. sinuata (W. Smith) Grun. var. sinuata | | | | | 1 | | | 0.10 |
| N. sinuata var. tabellariae Grun. | | | | | | | | |
| Pinnularia braunii var. amphicephala (A. Mayer) Hust. | | | | | | | | |
| P. sp. No. 1: 20$\mu$ long, 5$\mu$ wide; striae fine, 24/10 | 1 | 1 | | 0.20 | 2 | | | 0.20 |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | 3 | 47 | | 5.06 | 6 | 4 | | 0.99 |
| Stauroneis ignorata Hust. var. ignorata | | | | | | | | |
| S. kriegeri Patr. var. kriegeri | | | | | | | | |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Stephanodiscus astraea (Ehr.) Grun. var. astraea | 1 | | | 0.10 | | | | |
| S. astraea var. minutula (Kuetz.) Grun. | | | | | | | | |
| S. invisitatus Hohn & Hellerm. sp. nov. var. invisitatus | 1 | | | 0.10 | 6 | 1 | | 0.69 |
| S. niagarae Ehr. var. niagarae | | 1 | | 0.10 | | | | |
| Surirella angusta Kuetz. var. angusta | | 4 | | 0.40 | 1 | 2 | | 0.30 |
| S. delicatissima Lewis var. delicatissima | 1 | | | 0.10 | | | | |
| S. linearis W. Sm. var. linearis | | | | | | 1 | | 0.10 |
| S. linearis var. constricta (E.) Grun. | | | | | | | | |
| S. ovata Kuetz. var. ovata | 2 | 2 | | 0.40 | 8 | 2 | | 0.99 |
| S. ovata var. pinnata W. Smith | | | | | | | | |
| Synedra acus Kuetz. var. acus | | | | | | | | |
| S. delicatissima W. Sm. var. delicatissima | 2 | | | 0.20 | | | | |
| S. goulardi Breb. var. goulardi | | | | | | | | |
| S. incisa Boyer var. incisa | | | | | | | | |
| S. parasitica (W. Sm.) Hust. var. parasitica | | | | | | | | |
| S. pulchella Ralfs ex. Kuetz. var. pulchella | | | | | | | | |
| S. pulchella var. lacerata Hust. | | | | | | 2 | | 0.20 |
| S. pulchella var. lanceolata O'Meara | | | | | | | | |
| S. radians Kuetz. var. radians | | | | | | | | |
| S. rumpens Kuetz. var. rumpens | 2 | 4 | | 0.61 | | | | |
| S. rumpens var. familiaris (Kuetz.) Hust. | | | | | 1 | | | 0.10 |
| S. rumpens var. meneghiniana Grun. | | | | | | | | |
| S. rumpens var. scotia Grun. | | | | | | | | |

APPENDIX IX Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| S. socia Wallace var. socia | 1 | 17 | | 1.82 | 13 | 16 | | 2.88 |
| S. ulna (Nitz.) Ehr. var. ulna | 4 | 7 | | 1.11 | 3 | 7 | | 0.99 |
| S. ulna var. contracta ostr. | | 2 | | 0.20 | 8 | 4 | | 1.19 |
| S. ulna var. ramesi (Herib.) Hust. | | | | | | | | |
| S. sp. | | 1 | | 0.10 | | | | |
| Tabellaria fenestrata (Lyngb.) Kuetz. var. fenestrata | | | | | 1 | | | 0.10 |
| Total Number of Taxa | 55 | 61 | | | 63 | 65 | | |
| Total Number of Individuals | 486 | 502 | | | 503 | 503 | | |

Appendix IX

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of
Periphyton Diatoms Collected from Three Natural Substrates
in the New River, Virgina
During June, 1975

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Achnanthes acares Hohn & Hellerm. sp. nov. var. acares | | | | | | | | |
| A. clevei Grun. var. clevei | | | | | | | | |
| A. clevei var. rostrata Hust. | | | | | | | | |
| A. exigua var. heterovalva Krasske | | | | | | | | |
| A. hauckiana Grun. var. hauckiana | | | | | | | | |
| A. lanceolata (Breb.) Grun. var. lanceolata | 2 | | | 0.20 | 11 | 39 | | 4.99 |
| A. lanceolata var. dubia Grun. | 3 | 11 | | 1.39 | | | | |
| A. linearis var. pusilla Grun. | 31 | 158 | | 18.82 | 49 | 206 | | 25.47 |
| A. minutissima Kuetz. var. minutissima | 13 | 37 | | 4.98 | 36 | 50 | | 8.59 |
| A. subhudsonis var. kraeuselli Choln. | 3 | 16 | | 1.89 | | | | |
| Amphora ovalis Kuetz. var. ovalis | | | | | | | | |
| A. ovalis var. pediculus Kuetz. | 2 | | | 0.20 | | | | |
| A. perpusilla Grun. var. perpusilla | | 12 | | 1.19 | | | | |
| A. veneta Kuetz var. veneta | | | | | | | | |
| A. sp. | | | | | | | | |

APPENDIX IX Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Asterionella formosa Hass. var. formosa | 16 | | | 1.59 | 2 | | | 0.20 |
| A. formosa var. gracillima (Hantz.) Grun. | | 6 | | 0.60 | | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | 1 | | | 0.10 | | | | |
| Cocconeis pediculus Ehr. var. pediculus | | 10 | | 0.99 | | | | |
| C. placentula var. euglypta (Ehr.) Cl. | 3 | 7 | | 0.99 | 12 | 1 | | 1.40 |
| C. placentula var. lineata (Ehr.) V. H. | | 1 | | 0.10 | | | | |
| Cyclotella comta (Ehr.) Kuetz. var. comta | 3 | | | 0.30 | | | | |
| C. meneghiniana Kuetz. var. meneghiniana | | | | | | | | |
| C. operculata (Ag.) Kuetz. var. operculata | | | | | | 1 | | 0.10 |
| C. pseudostelligera Hust. var. pseudostelligera | 5 | 5 | | 0.99 | 4 | | | 0.40 |
| C. stelligera Cl & Grun. var. stelligera | 1 | 2 | | 0.33 | | | | |
| C. sp. (girdle view). | | | | | | | | |
| Cymbella affinis Kuetz. var. affinis | | | | | 1 | | | 0.10 |
| C. perpusilla A. Cleve var. perpusilla | | 1 | | 0.10 | | 1 | | 0.10 |
| C. prostata (Berkeley) Cleve var. prostata | | | | | 1 | | | 0.10 |
| C. sinuata Gregory var. sinuata | | 2 | | 0.20 | | 2 | | 0.20 |
| C. tumida (Breb.) V. H. var. tumida | | | | | | | | |
| C. turgida (Gregory) Cl. var. turgida | | | | | | | | |
| C. ventricosa Kuetz. var. ventricosa | 4 | 30 | | 3.39 | 39 | 7 | | 4.59 |
| Diatoma vulgare Bory var. vulgare | 2 | 10 | | 1.19 | 3 | 77 | | 7.99 |
| D. vulgare var. breve Grun. | | | | | | 1 | | 0.10 |
| Fragilaria capucina var. mesolepta Rabh. | | | | | | | | |
| F. construens (Ehr.) Grun. var. construens | | | | | | | | |

APPENDIX IX Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| F. construens var. binodis (Ehr.) Grun. | | | | | | | | |
| F. construens var. pumila Grun. | | | | | | | | |
| F. crotonensis Kitton var. crotonensis | | | | | | | | |
| F. leptostauron var. dubia (Grun.) Hust. | | 1 | | 0.10 | | | | |
| F. pinnata Ehr. var. pinnata | | 2 | | 0.20 | | | | |
| F. pinnata var. lancettula (Schaum.) Hust. | | | | | | | | |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | | | | | | | | |
| F. (girdle view) | | | | | | 11 | | 1.10 |
| | | | | | | | | |
| Frustulia rhomboides (Ehr.) DeT. var. rhomboides | | | | | | | | |
| F. rhomboides var. amphipleuroides (Grun.) Cl. | | | | | | | | |
| F. rhomboides var. viridula (Breb) Cl. | | | | | | | | |
| F. vulgaris (Thwaites) DeT. var. vulgaris | 3 | | | 0.30 | | | | |
| F. sp. (girdle view) | | | | | | | | |
| | | | | | | | | |
| Gomphonema angustatum (Kuetz.) Rabh. var. angustatum | | 3 | | 0.30 | | | | |
| G. angustatum f. brevis A. Mayer | | | | | | 1 | | 0.10 |
| G. angustatum var. productum Grun. | | | | | | | | |
| G. angustatum var. productum f. typica Grun. | | | | | | | | |
| G. constrictum var. capitata (Ehr.) Cleve | | | | | | | | |
| G. constrictum var. capitata f. italicum A. Mayer | 2 | | | 0.20 | | | | |
| G. constrictum var. | | | | | 2 | | | 0.20 |
| G. gracile var. dichotomum A. Mayer | 1 | | | 0.10 | 2 | | | 0.20 |
| G. gracile var. lanceolata (Kuetz.) Cleve | | | | | | | | |
| G. olivaceum (Lyngb.)Kuetz. var. olivaceum | | | | | | | | |
| G. olivaceum var. olivaceum f. minutula A. Mayer | 1 | | | 0.10 | 1 | | | 0.10 |
| G. olivaceum var. olivaceum f. typica A. Mayer | | | | | 7 | | | 0.70 |
| G. olivaceum var. tenellum (Kuetz.) Cl. | 1 | 1 | | 0.20 | | | | |
| G. olivaceum var. vulgaris f. typica A. Mayer | | | | | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | | 1 | | 0.10 | | | | |

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| G. parvulum var. exilissima Grun. | | | | | 7 | | | 0.70 |
| G. parvulum var. micropus (Kuetz.) Cl. | | 8 | | 0.80 | | 2 | | 0.20 |
| G. parvulum var. subelliptica Cleve | | | | | 1 | | | 0.10 |
| Gyrosigma acuminatum (Kuetz.) Rabh. var. acuminatum | | | | | | | | |
| G. obtusatum (Sulliv. & Wormley) var. obtusatum | | | | | | | | |
| G. spencerii (Quek.) Griff. & Henfr. var. spencerii | | | | | 1 | | | 0.10 |
| G. spencerii var. curvula (Grun.) Reim. comb. nov. | | 1 | | 0.10 | | | | |
| Melosira distans (Ehr.) Kuetz. var. distans | | | | | | 3 | | 0.30 |
| M. granulata (E.) Ralfs var. granulata | | | | | | | | |
| M. islandica O. Muell. var. | | | | | | | | |
| M. italica (Ehr.) Kuetz. var. | 2 | | | 0.20 | | 2 | | 0.20 |
| M. varians C. A. Ag. var. varians | 6 | 4 | | 0.99 | 2 | 28 | | 3.00 |
| M. (valve view) | | | | | | | | |
| Meridion circulare (Grev.) Ag. var. circulare | | | | | | | | |
| M. circulare var. constrictum (Ralfs) V.H. | | | | | | | | |
| Navicula absoluta Hust. nov. sp. var. absoluta | | | | | | | | |
| N. accomoda Hust. var. accomoda | | | | | | | | |
| N. aikenensis Patr. var. aikenensis | | 1 | | 0.10 | 1 | | | 0.10 |
| N. arvensis Hust. var. arvensis | 1 | 1 | | 0.20 | 3 | | | 0.30 |
| N. capitata Ehr. var. capitata | | | | | | | | |
| N. cryptocephala Kuetz. var. cryptocephala | 3 | | | 0.30 | | | | |
| N. cryptocephala f. minuta Boye P. | | | | | | | | |
| N. cryptocephala var. veneta (Kuetz.) Grun. | 7 | | | 0.70 | 10 | | | 1.00 |
| N. decussis ostr. var. decussis | | | | | | | | |
| N. elginensis var. neglecta (Krasske) Patr. comb. nov. | | | | | | | | |
| N. exigua (Gregory) O. Mueller var. exigua | | | | | | | | |

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. frugalis Hust. var. frugalis | 1 | | | 0.10 | 1 | | | 0.10 |
| N. graciloides A. Mayer var. graciloides | | | | | | | | |
| N. gregaria Donk. var. gregaria | 62 | 7 | | 6.87 | 33 | | | 3.30 |
| N. habergii Hust. var. hambergii | | | | | | | | |
| N. hustedtii Krasske var. hustedtii | | | | | | | | |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | 18 | 4 | | 2.19 | 14 | 6 | | 2.00 |
| N. laterostrata Hust. var. laterostrata | | | | | | | | |
| N. menisculus var. upsaliensis (Grun.) Grun. | | | | | | | | |
| N. minima Grun. var. minima | 11 | 27 | | 3.78 | 7 | | | 0.70 |
| N. minuscula Grun. var. minuscula | | 2 | | 0.20 | | | | |
| N. muraloides Hust. nov. sp. var. muraloides | | | | | | | | |
| N. mutica Kuetz. var. mutica | 1 | | | 0.10 | 6 | | | 0.60 |
| N. mutica var. stigma Patr. | 1 | | | 0.10 | | | | |
| N. mutica var. tropica Hust. | 22 | 1 | | 2.29 | | 1 | | 0.10 |
| N. mutica var. undulata (Hilse) Grun. | 19 | | | 1.89 | 5 | | | 0.50 |
| N. odiosa Wallace var. odiosa | | | | | | | | |
| N. pelliculosa (Breb. ex. Kuetz.) Hilse var. pelliculosa | | | | | | | | |
| N. pseudoreinhardtii Patr. var. pseudoreinhardtii | | 2 | | 0.20 | | | | |
| N. pupula Kuetz. var. pupula | | 1 | | 0.10 | | | | |
| N. pupula var. capitata Skv. & Meyer | 1 | | | 0.10 | | | | |
| N. pupula var. rectangularis (Greg.) Grun. | 1 | | | 0.10 | | | | |
| N. radiosa var. parva Wallace | | | | | | | | |
| N. radiosa var. tenella (Breb. ex. Kuetz.) Grun. | 2 | | | 0.20 | | | | |
| N. rhynchocephala Kuetz. var. rhychocephala | | | | | | | | |
| N. rhynchocephala var. germanii (Wallace) Patr. comb. nov. | | | | | | | | |
| N. rotunda Hust. var. rotunda | | | | | | | | |
| N. sabiniana Patr. var. sabiniana | | | | | | | | |
| N. salinarum var. intermedia (Grun.) Cl. | 34 | 13 | | 4.68 | 39 | 12 | | 5.09 |
| N. schroeteri var. escambia Patr. | | | | | | | | |
| N. secreta var. apiculata Patr. | 1 | | | 0.10 | | 1 | | 0.10 |

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| N. sorella Hohn & Hellerm. var. sorella | 1 | | | 0.10 | | | | |
| N. symmetrica Patr. var. symmetrica | | | | | | | | |
| N. tripunctata ( O. F. Muell.) Bory var. tripunctata | 4 | 7 | | 1.09 | 3 | | | 0.30 |
| N. tripunctata var. schizomeroides (V.H.) Patr. | | | | | | | | |
| N. (girdle view) 16-20μ long, 12-14 striae/10 | | | | | | | | |
| N. (girdle view) 45μ long; 10 striae/10 | | | | | | | | |
| N. sp. No. 2: 50μ long, 8.5μ wide; 12 striae/10 c.f. N. symmetrica Patr. var. symmetrica | | 1 | | 0.10 | | | | |
| N. sp. No. 3: 17-18μ long, 5μ wide; 20 striae/10 c.f. N. menisculus var. upsaliensis (Grun.) Grun. | | 2 | | 0.20 | 1 | | | 0.10 |
| N. sp. No. 4: 10.5μ long, 5μ wide; 14 striae/10 | | | | | | | | |
| N. sp. No. 5: 10μ long, 6μ wide; 14-16 striae/10 c.f. N. odiosa Wallace var. odiosa | | | | | 1 | | | 0.10 |
| Neidium dubium (Ehr.) Cl. var. dubium | 1 | | | 0.10 | | | | |
| Nitzschia acicularis W. Smith var. acicularis | | | | | | | | |
| N. amphibia Grun. var. amphibia | 2 | | | 0.20 | | | | |
| N. bacata Hust. var. bacata | | | | | | | | |
| N. biacrula Hohn & Hellerm. sp. nov. var. biacrula | | | | | | | | |
| N. capitellata Hust. var. capitellata | 4 | | | 0.40 | 1 | | | 0.10 |
| N. clausii Hantzsch var. clausii | 1 | | | 0.10 | | | | |
| N. communis Rabh. var. communis | 6 | | | 0.60 | 9 | | | 0.90 |
| N. dissipata (Kuetz.) Grun. var. dissipata | 38 | 13 | | 5.08 | 42 | 11 | | 5.29 |
| N. elliptica Hust. var. elliptica | | | | | | | | |
| N. filiformis (W. Smith) Hust. var. filiformis | | | | | | | | |
| N. fonticola Grun. var. fonticola | 3 | 4 | | 0.70 | 2 | 2 | | 0.40 |
| N. frustulum (Kuetz.) Grun. var. frustulum | 33 | 9 | | 4.18 | 50 | 5 | | 5.49 |

APPENDIX IX Cont.

| | Station R-5 wood | rock | sediment | % | Station R-6 wood | rock | sediment | % |
|---|---|---|---|---|---|---|---|---|
| N. gracilis Hantzsch var. gracilis | 2 | | | 0.20 | | | | |
| N. kittonii H. L. Smith var. kittonii | | | | | | | | |
| N. kuetzingiana Hilse var. kuetzingiana | | | | | 1 | | | 0.10 |
| N. lacunarum Hust. var. lacunarum | | | | | | | | |
| N. legleri Hust. var. legleri | | | | | | | | |
| N. linearis W. Smith var. linearis | 8 | 1 | | 0.90 | 3 | | | 0.30 |
| N. microcephala Grun. var. microcephala | | | | | | | | |
| N. palea (Kuetz.) W. Smith var. palea | 38 | 7 | | 4.48 | 13 | 2 | | 1.50 |
| N. paleacea Grun. var. paleacea | | | | | 1 | | | 0.10 |
| N. paleaeformis Hust. nov. sp. var. paleaeformis | | | | | 2 | | | 0.20 |
| N. parvula Lewis var. parvula | 22 | 1 | | 2.29 | 9 | 1 | | 1.00 |
| N. recta Hantzsch var. recta | | | | | | | | |
| N. romana Grun. var. romana | | | | | | | | |
| N. sigma (Kuetz.) W. Smith var. sigma | | 2 | | 0.20 | | | | |
| N. sigmoidea (Ehr.) W. Smith var. sigmoidea | | | | | | | | |
| N. sinuata (W. Smith) Grun. var. sinuata | | | | | | | | |
| N. sinuata var. tabellariae Grun. | | | | | | | | |
| Pinnularia braunii var. amphicephala (A. Mayer) Hust. | | | | | | | | |
| P. sp. No. 1: 20μ long, 5μ wide; striae fine, 24/10 | | | | | | | | |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | 1 | 40 | | 4.08 | 2 | 3 | | 0.50 |
| Stauroneis ignorata Hust. var. ignorata | 1 | | | 0.10 | | | | |
| S. kriegeri Patr. var. kriegeri | | 1 | | 0 10 | | | | |
| Stephanodiscus astraea (Ehr.) Grun. var. astraea | | | | | | | | |
| S. astraea var. minutula (Kuetz.) Grun. | | | | | | 2 | | 0.20 |
| S. invisitatus Hohn & Hellerm. sp. nov. var. invisitatus | 3 | | | 0.30 | 1 | | | 0.10 |
| S. niagarae Ehr. var. niagarae | | | | | | | | |

APPENDIX IX Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| Surirella angusta Kuetz. var. angusta | | | | | 5 | | | 0.50 |
| S. delicatissima Lewis var. delicatissima | | 1 | | 0.10 | | | | |
| S. linearis W. Sm. var. linearis | 5 | | | 0.50 | | | | |
| S. linearis var. constricta (E.) Grun. | 1 | | | 0.10 | | | | |
| S. ovata Kuetz. var. ovata | 8 | | | 0.80 | 7 | | | 0.70 |
| S. ovata var. pinnata W. Smith | | 2 | | 0.20 | | | | |
| Synedra acus Kuetz. var. acus | | | | | | 4 | | 0.40 |
| S. delicatissima W. Sm. var. delicatissima | | | | | | | | |
| S. goulardi Breb. var. goulardi | | | | | | | | |
| S. incisa Boyer var. incisa | | | | | | | | |
| S. parasitica (W. Sm.) Hust. var. parasitica | | | | | | | | |
| S. pulchella Ralfs ex. Kuetz. var. pulchella | | 1 | | 0.10 | 1 | | | 0.10 |
| S. pulchella var. lacerata Hust. | | | | | | | | |
| S. pulchella var. lanceolata O'Meara | | | | | | 1 | | 0.10 |
| S. radians Kuetz. var. radians | | 1 | | 0.10 | | | | |
| S. rumpens Kuetz. var. rumpens | | | | | 1 | | | 0.10 |
| S. rumpens var. familiaris (Kuetz.) Hust. | 7 | 3 | | 0.99 | 1 | 7 | | 0.80 |
| S. rumpens var. meneghiniana Grun. | | | | | | | | |
| S. rumpens var. scotia Grun. | | | | | | | | |
| S. socia Wallace var. socia | 9 | 11 | | 1.99 | 34 | 3 | | 3.69 |
| S. ulna (Nitz.) Ehr. var. ulna | 7 | 6 | | 1.29 | 4 | | | 0.40 |
| S. ulna var. contracta ostr. | 8 | | | 0.80 | 6 | 6 | | 1.20 |
| S. ulna var. ramesi (Herib.) Hust. | | | | | | 1 | | 0.10 |
| S. sp. | | | | | | | | |

APPENDIX IX Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | wood | rock | sediment | % | wood | rock | sediment | % |
| <u>Tabellaria fenestrata</u> (Lyngb.) Kuetz. var. <u>fenestrata</u> | | | | | | | | |
| Total Number of Taxa | 61 | 52 | | | 52 | 33 | | |
| Total Number of Individuals | 503 | 501 | | | 500 | 501 | | |

APPENDIX X

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of Periphyton Diatoms Collected From
Three Replicate Artificial Substrates, New River, Virginia.
October - November 1976

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| *Achnanthes exigua* Grun. var. *exigua* | | 1 | | 0.07 | | NS* | | |
| *A. lanceolata* (Breb.) Grun. var. *lanceolata* | 7 | 5 | | 0.80 | | | | |
| *A. lanceolata* var. *dubia* Grun. | 3 | 1 | | 0.33 | | | | |
| *A. linearis* var. *pusilla* Grun. | | | | | | | | |
| *A. minutissima* Kuetz. var. *minutissima* | 33 | 33 | 6 | 4.80 | | | | |
| *Amphipleura pellucida* Kuetz. var. *pullucida* | | | | | | | | |
| *Amphora ovalis* var. *pediculus* Kuetz. | | | | | | | | |
| *Caloneis bacillum* (Grun.) Cl. var. *bacillum* | | | | | | | | |
| *Cocconeis placentula* var. *euglypta* (Ehr.) Cl. | 118 | 105 | 185 | 27.23 | | | | |
| *C. placentula* var. *lineata* (Ehr.) V.H. | 324 | 188 | 301 | 54.24 | | | | |
| *Cyclotella meneghiniana* Kuetz. var. *meneghiniana* | | | | | | | | |
| *C. stelligera* Cl. & Grun. var. *stelligera* | | 2 | | 0.13 | | | | |

APPENDIX X Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Cymbella cymbiformis (Ag. Kuetz.) V.H. var. cymbiformis | | 1 | | 0.07 | | | | |
| C. microcephala Grun. var. microcephala | | | | | | | | |
| C. ventricosa Kuetz. var. ventricosa | | 1 | | 0.07 | | | | |
| Diploneis puella (Schum.) Cl. var. puella | | | 1 | 0.07 | | | | |
| Eunotia tenella (Grun.) Hust. var. tenella | | | | | | | | |
| E. (g.v.) 58.8 μ long; 11-12 striae/10 | | | | | | | | |
| E. (g.v.) 33.6 μ long; 16 striae/10 | | | | | | | | |
| Fragilaria crotonensis Kitton var. crotonensis | | 48 | | 3.20 | | | | |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 2 | 3 | | 0.33 | | | | |
| Frustulia vulgaris (Thwaites) DeT. var. vulgaris | | | | | | | | |
| Gomphonema angustatum (Kuetz.) Rabh. var. angustatum | | | | | | | | |
| G. augur (Ehr.) var. augur | | | | | | | | |
| G. bohemicum Reichelt & Fricke var. bohemicum | | | | | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | | | | | |
| G. sp. 1 36.6 μ long, 7.2 μ wide; 11 striae/10 | | | 1 | 0.07 | | | | |
| Gyrosigma scalproides (Rabh.) Cl. var. scalproides | | | | | | | | |
| Melosira granulata (E.) Ralfs var. granulata | | 3 | | 0.20 | | | | |
| M. granulata var. angustissima Muell. | | | | | | | | |
| M. varians C.A. Ag. var. varians | | | | | | | | |
| Navicula aikenensis Patr. var. aikenensis | 2 | 14 | 1 | 1.13 | | | | |
| N. capitata Ehr. var. capitata | | | | | | | | |
| N. cincta (Ehr.) Ralfs var. cincta | | | | | | | | |

APPENDIX X Cont.

| | Station R-1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| N. cryptocephala Kuetz. var. cryptocephala | | 3 | | 0.20 | | | | |
| N. decussis Ostr. var. decussis | | | | | | | | |
| N. gregaria Donk. var. gregaria | | | | | | | | |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | | | | | | | |
| N. menisculus var. upsaliensis (Grun.) Grun. | | 1 | | 0.07 | | | | |
| N. minima Grun. var. minima | | | | | | | | |
| N. muralis Grun. var. muralis | 7 | 8 | | 1.00 | | | | |
| N. pseudoatomus Lund. var. pseudoatomus | | | | | | | | |
| N. radiosa var. tenella (Breb. ex. Kuetz.) Grun. | | 1 | | 0.07 | | | | |
| N. salinarum var. intermedia (Grun.) Cl. | | 4 | | | | | | |
| N. symmetrica Patr. var. symmetrica | | 1 | 1 | 0.26 | | | | |
| N. viridula var. avenacea (Breb. ex. Grun.) V.H. | | | | | | | | |
| N. viridula var. rostellata (Kuetz. ) Cl. | | 1 | | 0.07 | | | | |
| | | | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | | | | | | | | |
| N. amphibia Grun. var. amphibia | | 1 | | 0.07 | | | | |
| N. clausii Hantzsch var. clausii | | | | | | | | |
| N. fasiculata Grun. var. fasiculata | | | | | | | | |
| N. fonticola Grun. var. fonticola | | 2 | | 0.13 | | | | |
| N. linearis W. Smith var. linearis | 1 | | | 0.07 | | | | |
| N. palea (Kuetz.) W. Smith var. palea | 2 | 18 | | 1.33 | | | | |
| | | | | | | | | |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | | | | | | | |
| | | | | | | | | |
| Surirella angusta Kuetz. var. angusta | | | | | | | | |
| S. ovalis Breb. var. ovalis | | | | | | | | |
| S. ovata Kuetz. var. ovata | | | | | | | | |

APPENDIX X Cont.

| | Station R- 1 | | | | Station R-2 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| _Synedra_ _pulchella_ Ralfs ex. Kuetz. var. _pulchella_ | | 4 | | 0.27 | | | | |
| _S._ _rumpens_ var. _meneghiniana_ Grun. | | 14 | | 0.94 | | | | |
| _S._ _ulna_ var. _ramesi_ (Herib.) Hust. | | 8 | | 0.53 | | | | |
| _S._ _ulna_ var. _oxyrhynchus_ fo. contracta Hust. | | 28 | 4 | 2.13 | | | | |
| _S._ (girdle view) | | | | | | | | |
| Total Number of Taxa | 10 | 27 | 8 | | | | | |
| Total Number of Individuals | 499 | 500 | 500 | | | | | |

*Due to substrate limitations no samples were collected

AD-A036 777    ENVIRONMENTAL CONTROL TECHNOLOGY CORP ANN ARBOR MICH    F/G 13/2
AQUATIC FIELD SURVEYS AT IOWA, RADFORD, AND JOLIET ARMY AMMUNIT--ETC(U)
MAR 76   R L WEITZEL, R EISENMAN, J E SCHENK    DAMD17-75-C-5046

UNCLASSIFIED    NL

5 OF 5
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APPENDIX X

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of Periphyton Diatoms Collected From
Three Replicate Artificial Substrates, New River, Virginia.
October - November 1975

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Achnanthes exigua Grun. var. exigua | 1 | | | 0.07 | | | | |
| A. lanceolata (Breb.) Grun. var. lanceolata | 2 | 4 | 6 | 0.80 | | | | |
| A. lanceolata var. dubia Grun. | 1 | | | 0.07 | 3 | | | 0.20 |
| A. linearis var. pusilla Grun. | 13 | 12 | 19 | 2.93 | 2 | 1 | 3 | 0.40 |
| A. minutissima Kuetz. var. minutissima | 34 | 11 | 31 | 5.07 | 5 | 8 | 16 | 1.93 |
| Amphipleura pellucida Kuetz. var. pullucida | | | | | | | | |
| Amphora ovalis var. pediculus Kuetz. | | 1 | | 0.07 | | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | | | | | | | | |
| Cocconeis placentula var. euglypta (Ehr.) Cl. | 183 | 206 | 216 | 40.33 | 227 | 248 | 284 | 50.60 |
| C. placentula var. lineata (Ehr.) V.H. | 205 | 255 | 219 | 45.27 | 252 | 243 | 194 | 45.93 |

APPENDIX X Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Cyclotella meneghiniana Kuetz. var. meneghiniana | 1 | | | 0.07 | | | | |
| C. stelligera Cl. & Grun. var. stelligera | 1 | | | 0.07 | | | | |
| Cymbella cymbiformis (Ag. Kuetz.) V.H. var. cymbiformis | | | | | | | | |
| C. microcephala Grun. var. microcephala | | | | | | | | |
| C. ventricosa Kuetz. var. ventricosa | 1 | | | 0.07 | | | | |
| Diploneis puella (Schum.) Cl. var. puella | | | | | | | | |
| Eunotia tenella (Grun.) Hust. var. tenella | | | | | | | | |
| E. (g.v.) 58.8 μ long; 11-12 striae/10 | 1 | | | 0.07 | | | | |
| E. (g.v.) 33.6 μ long; 16 striae/10 | | | | | | | | |
| Fragilaria crotonensis Kitton var. crotonensis | 7 | | | 0.47 | | | | |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 7 | 2 | 1 | 0.67 | | | | |
| Frustulia vulgaris (Thwaites) DeT. var. vulgaris | 1 | | | 0.07 | | | | |
| Gomphonema angustatum (Kuetz.) Rabh. var. angustatum | | 2 | | 0.13 | | | | |
| G. augur (Ehr.) var. augur | | | | | | | | |
| G. bohemicum Reichelt & Fricke var. bohemicum | | | 1 | 0.07 | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | 9 | . | 3 | 0.80 | 2 | | | 0.13 |
| G. sp. 1 36.6 μ long, 7.2 μ wide; 11 striae/10 | | | | | | | | |
| Gyrosigma scalproides (Rabh.) Cl. var. scalproides | 1 | | | 0.07 | 1 | | | 0.07 |
| Melosira granulata (E.) Ralfs var. granulata | | | | | | | | |
| M. granulata var. angustissima Muell. | | | | | | | | |
| M. varians C.A. Ag. var. varians | 2 | | | 0.13 | | | | |

APPENDIX X Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Navicula aikenensis Patr. var. aikenensis | | 1 | 1 | 0.13 | 1 | | | 0.07 |
| N. capitata Ehr. var. capitata | | | | | | | | |
| N. cincta (Ehr.) Ralfs var. cincta | | | | | | | | |
| N. cryptocephala Kuetz. var. cryptocephala | 2 | | | 0.13 | | | | |
| N. decussis Ostr. var. decussis | 1 | | | 0.07 | | | | |
| N. gregaria Donk. var. gregaria | 3 | | | 0.20 | 2 | | | 0.13 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | | | | | | | |
| N. menisculus var. upsaliensis (Grun.) Grun. | | | | | | | | |
| N. minima Grun. var. minima | 2 | | | 0.13 | | | | |
| N. muralis Grun. var. muralis | | | | | | | | |
| N. pseudoatomus Lund. var. pseudoatomus | | | | | | | 1 | 0.07 |
| N. radiosa var. tenella (Breb. ex. Kuetz.) Grun. | | | | | | | | |
| N. salinarum var. intermedia (Grun.) Cl. | | | | | | | | |
| N. symmetrica Patr. var. symmetrica | 2 | | | 0.13 | | | | |
| N. viridula var. avenacea (Breb. ex. Grun.) V.H. | | | | | 1 | | | 0.07 |
| N. viridula var. rostellata (Kuetz. ) Cl. | | | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | 1 | | | 0.07 | | | | |
| N. amphibia Grun. var. amphibia | 3 | | | 0.20 | | | | |
| N. clausii Hantzsch var. clausii | | | | | 1 | | | 0.07 |
| N. fasiculata Grun. var. fasiculata | | 1 | | 0.07 | | | | |
| N. fonticola Grun. var. fonticola | 4 | 1 | | 0.33 | | | | |
| N. linearis W. Smith var. linearis | | | | | | | | |
| N. palea (Kuetz.) W. Smith var. palea | | 3 | | 0.20 | 1 | | 1 | 0.13 |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | | | | 2 | | | 0.13 |
| Surirella angusta Kuetz. var. angusta | 2 | | 2 | 0.27 | | | 1 | 0.07 |
| S. ovalis Breb. var. ovalis | | | | | | | | |
| S. ovata Kuetz. var. ovata | 1 | | 1 | 0.13 | | | | |

APPENDIX X Cont.

| | Station R-3 | | | | Station R-4 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| *Synedra pulchella* Ralfs ex. Kuetz. var. *pulchella* | | | | | | | | |
| *S. rumpens* var. *meneghiniana* Grun. | | | | | | | | |
| *S. ulna* var. *ramesi* (Herib.) Hust. | | | | | | | | |
| *S. ulna* var. *oxyrhynchus* fo. contracta Hust. | 9 | 1 | | 0.67 | | | | |
| *S.* (girdle view). | | | | | | | | |
| Total Number of Taxa | 28 | 13 | 11 | | 13 | 4 | 7 | |
| Total Number of Individuals | 500 | 500 | 500 | | 500 | 500 | 500 | |

APPENDIX X

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of Periphyton Diatoms Collected From
Three Replicate Artificial Substrates, New River, Virginia.
October - November 1975

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Achnanthes exigua Grun. var. exigua | | NS* | | | | | | |
| A. lanceolata (Breb.) Grun. var. lanceolata | | | | | 7 | 5 | 11 | 1.53 |
| A. lanceolata var. dubia Grun. | | | | | 8 | 3 | 4 | 1.00 |
| A. linearis var. pusilla Grun. | | | | | 53 | 21 | 25 | 6.60 |
| A. minutissima Kuetz. var. minutissima | | | | | 59 | 20 | 22 | 6.73 |
| Amphipleura pellucida Kuetz. var. pullucida | | | | | 2 | | | 0.13 |
| Amphora ovalis var. pediculus Kuetz. | | | | | | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | | | | | 2 | | | 0.13 |
| Cocconeis placentula var. euglypta (Ehr.) Cl. | | | | | 72 | 145 | 164 | 25.40 |
| C. placentula var. lineata (Ehr.) V.H. | | | | | 148 | 290 | 258 | 46.40 |
| Cyclotella meneghiniana Kuetz. var. meneghiniana | | | | | | | | |
| C. stelligera Cl. & Grun. var. stelligera | | | | | | | | |

APPENDIX X Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Cymbella cymbiformis (Ag. Kuetz.) V.H. var. cymbiformis | | | | | | | | |
| C. microcephala Grun. var. microcephala | | | | | | | | |
| C. ventricosa Kuetz. var. ventricosa | | | | | | | | |
| Diploneis puella (Schum.) Cl. var. puella | | | | | | | | |
| Eunotia tenella (Grun.) Hust. var. tenella | | | | | 1 | | | 0.07 |
| E. (g.v.) 58.8 μ long; 11-12 striae/10 | | | | | 1 | | 1 | 0.13 |
| E. (g.v.) 33.6 μ long; 16 striae/10 | | | | | | | | |
| Fragilaria crotonensis Kitton var. crotonensis | | | | | 3 | | 1 | 0.27 |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | | | | | 10 | | | 0.67 |
| Frustulia vulgaris (Thwaites) DeT. var. vulgaris | | | | | | | | |
| Gomphonema angustatum (Kuetz.) Rabh. var. angustatum | | | | | 9 | | 2 | 0.73 |
| G. augur (Ehr.) var. augur | | | | | 1 | | | 0.13 |
| G. bohemicum Reichelt & Fricke var. bohemicum | | | | | 4 | | | 0.27 |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | | 21 | 6 | 6 | 2.20 |
| G. sp. 1 36.6 μ long, 7.2 μ wide; 11 striae/10 | | | | | | | | |
| Gyrosigma scalproides (Rabh.) Cl. var. scalproides | | | | | | | | |
| Melosira granulata (E.) Ralfs var. granulata | | | | | | | | |
| M. granulata var. angustissima Muell. | | | | | 9 | | | 0.60 |
| M. varians C.A. Ag. var. varians | | | | | 7 | | | 0.47 |
| Navicula aikenensis Patr. var. aikenensis | | | | | 2 | | | 0.13 |
| N. capitata Ehr. var. capitata | | | | | 3 | | | 0.20 |

APPENDIX X Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| N. cincta (Ehr.) Ralfs var. cincta | | | | | 6 | | | 0.40 |
| N. cryptocephala Kuetz. var. cryptocephala | | | | | | | | |
| N. decussis Ostr. var. decussis | | | | | 4 | | | 0.27 |
| N. gregaria Donk. var. gregaria | | | | | 7 | 2 | | 0.60 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | | | | | 2 | | 1 | 0.20 |
| N. menisculus var. upsaliensis (Grun.) Grun. | | | | | | | | |
| N. minima Grun. var. minima | | | | | 12 | 3 | | 1.00 |
| N. muralis Grun. var. muralis | | | | | | | | |
| N. pseudoatomus Lund. var. pseudoatomus | | | | | 2 | | | 0.13 |
| N. radiosa var. tenella (Breb. ex. Kuetz.) Grun. | | | | | | | | |
| N. salinarum var. intermedia (Grun.) Cl. | | | | | 4 | 2 | 1 | 0.47 |
| N. symmetrica Patr. var. symmetrica | | | | | 2 | | | 0.13 |
| N. viridula var. avenacea (Breb. ex. Grun.) V.H. | | | | | | | | |
| N. viridula var. rostellata (Kuetz. ) Cl. | | | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | | | | | 1 | | | 0.07 |
| N. amphibia Grun. var. amphibia | | | | | 2 | | 1 | 0.20 |
| N. clausii Hantzsch var. clausii | | | | | 1 | | | 0.07 |
| N. fasiculata Grun. var. fasiculata | | | | | | | | |
| N. fonticola Grun. var. fonticola | | | | | 2 | | | 0.13 |
| N. linearis W. Smith var. linearis | | | | | 1 | | | 0.07 |
| N. palea (Kuetz.) W. Smith var. palea | | | | | 23 | 2 | 1 | 1.73 |
| Rhoicosphenia curvata (Kuetz.) Grun. var. curvata | | | | | 1 | | 1 | 0.13 |
| Surirella angusta Kuetz. var. angusta | | | | | 1 | 1 | 1 | 0.20 |
| S. ovalis Breb. var. ovalis | | | | | | | | |
| S. ovata Kuetz. var. ovata | | | | | | | | |

APPENDIX X Cont.

| | Station R-5 | | | | Station R-6 | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | % | 1 | 2 | 3 | % |
| Synedra pulchella Ralfs ex. Kuetz. var. pulchella | | | | | | | | |
| S. rumpens var. meneghiniana Grun. | | | | | | | | |
| S. ulna var. ramesi (Herib.) Hust. | | | | | | | | |
| S. ulna var. oxyrhynchus fo. contracta Hust. | | | | | 7 | | | 0.47 |
| S. (girdle view). | | | | | | | | |
| Total Number of Taxa | | | | | 37 | 12 | 16 | |
| Total Number of Individuals | | | | | 500 | 500 | 500 | |

*Due to substrates limitations no samples were collected

APPENDIX XI
RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of Periphyton Diatoms Collected
From Three Natural Substrates in the New River, Virginia
During November, 1975

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| Achnanthes clevei Grun. var. clevei | | | | | | |
| A. exigua Grun. var. exigua | 1 | | 0.10 | | | |
| A. exigua var. heterovalva Krasske | | | | | | |
| A. lanceolata (Breb.) Grun. var. lanceolata | 3 | 6 | 0.90 | | 1 | 0.10 |
| A. lanceolata var. dubia Grun. | | 1 | 0.10 | | 1 | 0.10 |
| A. linearis var. pusilla Grun. | 20 | 36 | 5.56 | 42 | 83 | 12.5 |
| A. minutissima Kuetz. var. minutissima | 17 | 18 | 3.47 | 21 | 19 | 4.0 |
| Amphiplerua pellucida Kuetz. var. pellucida | | | | | 1 | 0.10 |
| Amphora ovalis var. pediculus Kuetz. | 2 | 2 | 0.40 | | 1 | 0.10 |
| A. veneta Kuetz. var. veneta | | | | | | |
| Anomoeoneis serians var. brachysira (Breb. ex Kuetz.) Hust. | 1 | | 0.10 | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | | | | | 1 | 0.10 |
| Cocconeis pediculus Ehr. var. pediculus | | | | | | |
| C. placentula var. euglypta (Ehr.) Cl. | 3 | 2 | 0.50 | 3 | 2 | 0.50 |
| C. placentula var. lineata (Ehr.) V.H. | 4 | 2 | 0.60 | 6 | 4 | 1.00 |
| Cyclotella meneghiniana Kuetz. var. meneghinana | 1 | | 0.10 | 1 | | 0.10 |
| C. operculata (Ag.) Kuetz. var. operculata | 1 | | 0.10 | | | |
| C. stelligera Cl. & Grun. var. stelligera | | 6 | 0.60 | | 1 | 0.10 |
| Cymbella affinis Kuetz. var. affinis | | | | | | |
| C. tumida (Breb.) V.H. var. tumida | 2 | 1 | 0.30 | 2 | | 0.20 |
| C. ventricosa Kuetz. var. ventricosa | 1 | 1 | 0.20 | 1 | 2 | 0.30 |

APPENDIX VII (cont.)

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| Denticula tenuris var. crassula (Naegeli) Hust. | | 1 | 0.10 | | | |
| Diatoma vulgare Bory var. vulgare | | | | | | |
| Diploneis puella (Schum.) Cl. var. puella | 2 | | 0.20 | | | |
| Eunotia g.v. 37.2 μ long, 12 μ wide, 18 striae in 10 | | | | | 2 | 0.20 |
| E. pectinalis (O. F. Mull.) Rabh. var. pectinalis | 1 | | 0.10 | | | |
| E. vanheurckii var. intermedia (Krasske ex. Hust.) Patr. | | | | | | |
| Fragilaria construens (Ehr.) Grun. var. construens | | 1 | 0.10 | | | |
| F. crotonensis Kitton var. crotonensis | | 3 | 0.30 | | | |
| F. *crotonensis* var. *oregona* Sov. | | | | 2 | 1 | 0.30 |
| F. leptostauron var. dubia (Grun.) Hust. | | | | | | |
| F. pinnata Ehr. var. pinnata | | | | 2 | | 0.20 |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 9 | 2 | 1.09 | 4 | 5 | 0.90 |
| Frustulia asymmetrica (Cl) Hust. var. asymmetrica | | | | | | |
| F. rhomboides var. amphipleuroides (Grun.) Cl. | | | | | | |
| F. rhomboides var. capitata (A. Mayer) Patr. comb. nov. | | | | | | |
| F. vulgaris (Thwaites) DeT. var. vulgaris | 2 | 5 | 0.70 | 2 | 5 | 0.70 |
| *Gomphonema abbreviatum* Ag. Kuetz. *var. abbreviatum* | | | | | | |
| G. angustatum (Kuetz.) Rahb. var. angustatum | 2 | 5 | 0.70 | 3 | | 0.30 |
| G. augur Ehr. var. augur | | | | 1 | | 0.10 |
| G. bohemicum Reichelt et Fricke var. bohemicum | 1 | | 0.10 | 3 | 1 | 0.40 |
| G. olivaceum (Lyngb.) Kuetz. var. olivaceum | | | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | 1 | | 0.10 | | 2 | 0.20 |
| Gyrosigma acuminatum (Kuetz.) Rabh. var. acuminatum | 2 | 4 | 0.60 | 3 | 4 | 0.70 |
| G. exilis (Grun.) Reim. comb. nov., var. exilis | | | | 1 | | 0.10 |
| G. scalproides (Rabh.) Cl. var. scalproides | 14 | 12 | 2.58 | 1 | 14 | 1.50 |
| *Melosira granulata* (E.) Ralfs *var. granulata* | 6 | 18 | 2.38 | 13 | | 1.30 |
| M. granulata var. angustissima Mull. | 3 | | 0.30 | 1 | | 0.10 |
| M. italica (Ehr.) Kuetz. var. italica | | | | | | |
| M. varians C. A. Ag. var. varians | 3 | | 0.30 | 4 | | 0.40 |

APPENDIX VII (cont.)

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| Meridion circulare var. constrictum (Ralfs) V.H. | | 1 | 0.10 | | | |
| | | | | | | |
| Navicula aikenensis Patr. var. aikenensis | | 5 | 0.50 | 4 | 1 | 0.50 |
| N. arvensis Hust. var arvensis | | | | | | |
| N. capitata Ehr. var. capitata | 1 | | 0.10 | | | |
| N. cincta (Ehr.) Ralfs var. cincta | | | | 18 | 13 | 3.10 |
| N. confervacea var. peregrina (W. Sm.) Grun. | | 3 | 0.30 | | 2 | 0.20 |
| N. contenta var. biceps (Arn.) V.H. | | | | | 1 | 0.10 |
| N. cryptocephala Kuetz. var. cyptocephala | 3 | 6 | 0.90 | 19 | 5 | 2.40 |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | | | | | |
| N. decussis Ostr. var. decussis | 3 | 6 | 0.90 | | 4 | 0.40 |
| N. exigua (Gregory) O. Mueller var. exigua | | | | | | |
| N. gregaria Donk var. gregaria | 138 | 109 | 24.53 | 109 | 116 | 22.50 |
| N. gysingensis Foged var. gysingensis | | 4 | 0.40 | 1 | 1 | 0.20 |
| N. heufleri Grun. var. heufleri | | 4 | 0.40 | 1 | 3 | 0.40 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | 22 | 13 | 3.48 | 13 | 8 | 2.10 |
| N. *menisculus var. upsaliensis* (Grun.) Grun. | | | | | | |
| N. minima Grun. var. minima | 6 | 19 | 2.48 | | 9 | 0.90 |
| N. mutica Kuetz. var. mutica | | | | | | |
| N. mutica var. tropica Hust. | 2 | 3 | 0.50 | 5 | | 0.50 |
| N. mutica var. undulata (Hilse) Grun. | 31 | 43 | 7.35 | 37 | 1 | 3.80 |
| N. (c.f. paanaensis A. Cleve-Euler var. paanaensis) | | | | | | |
| N. pseudoatomus Lund. var. pseudoatomus | | | | | | |
| N. pupula Kuetz. var. pupula | 1 | | 0.10 | 1 | 1 | 0.20 |
| N. pupula var. capitata Skv. & Meyer | 9 | | 0.90 | 13 | 6 | 2.90 |
| N. pupula var. rectangularis (Greg.) Grun. | | | | 1 | | 0.10 |
| N. pygmaea Kuetz. var. pygmaea | 1 | 2 | 0.30 | 3 | 1 | 0.40 |
| N. radiosa var. tenella (Breb. ex Kuetz.) Grun. | 55 | 41 | 9.53 | 21 | 20 | 4.10 |
| N. salinarum var. intermedia (Grun.) Cl. | 8 | 5 | 1.29 | 13 | 2 | 1.50 |
| N. subhamulata Grun. var subhamulata | | | | | | |
| N. symmetrica Patr. var symmetrica | 14 | 11 | 2.48 | 6 | 9 | 1.50 |
| N. tripunctata (O. F. Muell.) Bory var tripunctata | | | | 2 | | 0.20 |
| N. viridula var. avenacea (Breb. ex Grun.) V.H. | 15 | 15 | 2.98 | 27 | 20 | 4.70 |
| N. viridula var. linearis Hust. | | | | | 2 | 0.20 |
| | | | | | | |
| Neidium dubium (Ehr.) Cl. var. dubium | | 1 | 0.10 | | | |
| | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | | | | 1 | | 0.10 |
| N. amphibia Grun. var. amphibia | 3 | 2 | 0.50 | 2 | 4 | 0.60 |
| N. clausii Hantzsch var. clausii | 20 | 5 | 2.48 | 14 | 36 | 5.00 |

APPENDIX VII (cont.)

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| N. dissipata (Kuetz.) Grun. var. dissipata | 7 | 3 | 1.00 | 8 | 5 | 1.30 |
| N. fonticola Grun. var. fonticola | | 9 | 0.90 | 3 | 13 | 1.60 |
| N. frustulum (Kuetz.) Grun. var. frustulum | 1 | | 0.10 | 1 | | 0.10 |
| N. hungarica Grun. var. hungarica | | | | | | |
| N. linearis W. Smith var. linearis | 1 | | 0.10 | | 1 | 0.10 |
| N. palea (Kuetz.) W. Smith var. palea | 45 | 40 | 8.44 | 43 | 38 | 8.10 |
| N. parvula Lewis var. parvula | 6 | 19 | 2.48 | 8 | 1 | 0.90 |
| N. sigma (Kuetz.) W. Smith var. sigma | 1 | | 0.10 | 2 | 15 | 1.70 |
| N. sinuata var. tabellaria Grun. | | 1 | 0.10 | | | |
| Pinnularia kneuckeri Hust. var kneuckeri | | | | | | |
| Rhoicosphenia curvata (Kuetz) Grun. var. curvata | 3 | 2 | 0.50 | 1 | 4 | 0.50 |
| Surirella angusta Kuetz. var. angusta | 1 | 7 | 0.80 | 4 | 6 | 1.00 |
| S. delicatissima Lewis var. delicatissima | | | | | | |
| S. ovalis Breb. var. ovalis | | 1 | 0.10 | | 1 | 0.10 |
| S. ovata Kuetz. var ovata | | 1 | 0.10 | | | |
| S. ovata var. pinnata W. Smith | | | | | | |
| S. tenera Greg. var. tenera | 2 | 1 | 0.30 | 3 | 1 | 0.40 |
| Synedra pulchella Ralfs. ex. Kuetz. var. pulchella | | | | | | |
| S. ulna (Nitz.) Ehr. var. ulna | | | | | | |
| S. ulna var. oxyrhynchus fo. contracta Hust. | | | | | | |
| Total number of taxa | 50 | 49 | | 50 | 51 | |
| Total number of individuals | 501 | 506 | | 500 | 500 | |

APPENDIX XI

RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of Periphyton Diatoms Collected
From Three Natural Substrates in the New River, Virginia
During November, 1975

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| Achnanthes clevei Grun. var. clevei | | | | 2 | 1 | 0.30 |
| A. exigua Grun. var. exigua | | | | | | |
| A. exigua var. heterovalva Krasske | | | | | 2 | 0.20 |
| A. lanceolata (Breb.) Grun. var. lanceolata | | 4 | 0.40 | 3 | 2 | 0.50 |
| A. lanceolata var. dubia Grun. | 3 | 4 | 0.70 | 6 | | 0.60 |
| A. linearis var. pusilla Grun. | 31 | 11 | 4.20 | 26 | 38 | 6.40 |
| A. minutissima Kuetz. var. minutissima | 11 | 7 | 1.80 | 10 | 18 | 2.80 |
| Amphiplerua pellucida Kuetz. var. pellucida | | | | 1 | | 0.10 |
| Amphora ovalis var. pediculus Kuetz. | 1 | | 0.10 | 32 | 1 | 3.30 |
| A. veneta Kuetz. var. veneta | 1 | | 0.10 | 12 | 1 | 1.30 |
| Anomoeoneis serians var. brachysira (Breb. ex Kuetz.) Hust. | | | | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | 1 | | 0.10 | 3 | 2 | 0.50 |
| Cocconeis pediculus Ehr. var. pediculus | | | | 1 | | 0.10 |
| C. placentula var. euglypta (Ehr.) Cl. | 3 | 2 | 0.50 | 1 | 7 | 0.80 |
| C. placentula var. lineata (Ehr.) V.H. | 4 | 1 | 0.50 | 5 | 4 | 0.90 |
| Cyclotella meneghiniana Kuetz. var. meneghinana | | | | | | |
| C. operculata (Ag.) Kuetz. var. operculata | | | | | | |
| C. stelligera Cl. & Grun. var. stelligera | 2 | 7 | 0.90 | | 2 | 0.20 |
| Cymbella affinis Kuetz. var. affinis | | | | 1 | | 0.10 |
| C. tumida (Breb.) V.H. var. tumida | 2 | | 0.20 | 3 | 1 | 0.40 |
| C. ventricosa Kuetz. var. ventricosa | 3 | 2 | 0.50 | 4 | | 0.40 |
| Denticula tenuris var. crassula (Naegeli) Hust. | | | | | | |
| Diatoma vulgare Bory var. vulgare | | | | | | |

APPENDIX VII (cont.)

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| Diploneis puella (Schum.) Cl. var. puella | | | | | | |
| Eunotia g.v. 37.2 μ long, 12 μ wide, 18 striae in 10 | | | | | | |
| E. pectinalis (O. F. Mull.) Rabh. var. pectinalis | | | | 1 | | 0.10 |
| E. vanheurckii var. intermedia (Krasske ex. Hust.) Patr. | | | | | | |
| Fragilaria construens (Ehr.) Grun. var. construens | | | | 1 | | 0.10 |
| F. crotonensis Kitton var. crotonensis | 2 | 3 | 0.50 | 3 | | 0.30 |
| F. crotonensis var. oregona Sov. | | | | | | |
| F. leptostauron var. dubia (Grun.) Hust. | | | | | | |
| F. pinnata Ehr. var. pinnata | | 1 | 0.10 | | 1 | 0.10 |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 4 | 3 | 0.70 | 2 | 4 | 0.60 |
| Frustulia asymmetrica (Cl.) Hust. var. asymmetrica | | | | | | |
| F. rhomboides var. amphipleuroides (Grun.) Cl. | | 1 | 0.10 | 1 | 1 | 0.20 |
| F. rhomboides var. capitata (A. Mayer) Patr. comb. nov. | | | | | | |
| F. vulgaris (Thwaites) DeT. var. vulgaris | | | | 4 | 3 | 0.70 |
| Gomphonema abbreviatum Ag. Kuetz. var. abbreviatum | | 3 | 0.30 | | | |
| G. angustatum (Kuetz.) Rahb. var. angustatum | | 3 | 0.30 | 3 | 2 | 0.50 |
| G. augur Ehr. var. augur | | | | | | |
| G. bohemicum Reichelt et Fricke var. bohemicum | | 2 | 0.20 | 2 | | 0.20 |
| G. olivaceum (Lyngb.) Kuetz. var. olivaceum | | 2 | 0.20 | | 1 | 0.10 |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | 1 | | 0.10 |
| Gyrosigma acuminatum (Kuetz.) Rabh. var. acuminatum | 9 | 2 | 1.10 | 3 | 6 | 0.90 |
| G. exilis (Grun.) Reim. comb. nov., var. exilis | | | | | | |
| G. scalproides (Rabh.) Cl. var. scalproides | 3 | 1 | 0.40 | 41 | 5 | 4.60 |
| Melosira granulata (E.) Ralfs var. granulata | 2 | 5 | 0.70 | 1 | | 0.10 |
| M. granulata var. angustissima Mull. | 3 | | 0.30 | | 1 | 0.10 |
| M. italica (Ehr.) Kuetz. var. italica | | | | | | |
| M. varians C. A. Ag. var. varians | 3 | 3 | 0.60 | | 3 | 0.30 |
| Meridion circulare var. constrictum (Ralfs) V.H. | | | | | | |

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| Navicula aikenensis Patr. var. aikenensis | | 2 | 0.20 | | 1 | 0.10 |
| N. arvensis Hust. var arvensis | | | | | | |
| N. capitata Ehr. var. capitata | 1 | | 0.10 | 1 | 1 | 0.20 |
| N. cincta (Ehr.) Ralfs var. cincta | 8 | 60 | 6.80 | 18 | 69 | 8.70 |
| N. confervacea var. peregrina (W. Sm.) Grun. | 1 | | 0.10 | | | |
| N. contenta var. biceps (Arn.) V.H. | | | | | | |
| N. cryptocephala Kuetz. var. cyptocephala | 4 | | 0.40 | | 2 | 0.20 |
| N. cryptocephala var. veneta (Kuetz.) Grun. | 10 | 33 | 4.30 | | 18 | 1.80 |
| N. decussis Ostr. var. decussis | 3 | 4 | 0.70 | 5 | 3 | 0.80 |
| N. exigua (Gregory) O. Mueller var. exigua | | | | 1 | | 0.10 |
| N. gregaria Donk var. gregaria | 54 | 58 | 11.20 | 54 | 94 | 14.80 |
| N. gysingensis Foged var. gysingensis | 1 | 1 | 0.20 | 3 | 3 | 0.60 |
| N. heufleri Grun. var. heufleri | 10 | 15 | 2.50 | 8 | 26 | 3.40 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | 6 | 7 | 1.30 | 1 | 5 | 0.60 |
| N. menisculus var. upsaliensis (Grun.) Grun. | 2 | | 0.20 | | | |
| N. minima Grun. var. minima | 1 | 7 | 0.80 | 33 | 6 | 3.90 |
| N. mutica Kuetz. var. mutica | | | | | | |
| N. mutica var. tropica Hust. | 8 | 2 | 1.00 | | 1 | 0.10 |
| N. mutica var. undulata (Hilse) Grun. | 168 | 44 | 21.20 | 6 | 29 | 3.20 |
| N. (c.f. paanaensis A. Cleve-Euler var. paanaensis) | | | | | | |
| N. pseudoatomus Lund. var. pseudoatomus | | | | | | |
| N. pupula Kuetz. var. pupula | | | | | 1 | 0.10 |
| N. pupula var. capitata Skv. & Meyer | 3 | | 0.30 | 1 | | 0.10 |
| N. pupula var. rectangularis (Greg.) Grun. | 1 | | 0.10 | | | |
| N. pygmaea Kuetz. var. pygmaea | 1 | | 0.10 | | | |
| N. radiosa var. tenella (Breb. ex Kuetz.) Grun. | 23 | 22 | 4.50 | 23 | 9 | 3.10 |
| N. salinarum var. intermedia (Grun.) Cl. | 10 | 6 | 1.60 | 4 | 4 | 0.80 |
| N. subhamulata Grun. var subhamulata | | | | | | |
| N. symmetrica Patr. var symmetrica | 3 | 34 | 3.70 | 10 | 7 | 1.70 |
| N. tripunctata (O. F. Muell.) Bory var tripunctata | | | | | | |
| N. viridula var. avenacea (Breb. ex Grun.) V.H. | 17 | 21 | 3.80 | 17 | 22 | 3.90 |
| N. viridula var. linearis Hust. | 1 | 1 | 0.20 | | | |
| | | | | | | |
| Neidium dubium (Ehr.) Cl. var. dubium | | | | | | |
| | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | 1 | | 0.10 | 2 | | 0.20 |
| N. amphibia Grun. var. amphibia | 2 | 2 | 0.40 | 20 | 11 | 3.10 |
| N. clausii Hantzsch var. clausii | 2 | 20 | 2.20 | 22 | 11 | 3.30 |
| N. dissipata (Kuetz.) Grun. var. dissipata | 9 | 1 | 1.00 | 9 | 4 | 1.30 |
| N. fonticola Grun. var. fonticola | | 7 | 0.70 | 10 | 11 | 2.10 |
| N. frustulum (Kuetz.) Grun. var. frustulum | 4 | | 0.40 | | | |

APPENDIX VII (cont.)

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| N. hungarica Grun. var. hungarica | 1 | | 0.10 | | | |
| N. linearis W. Smith var. linearis | | | | 2 | | 0.20 |
| N. palea (Kuetz.) W. Smith var. palea | 15 | 17 | 3.20 | 42 | 29 | 7.10 |
| N. parvula Lewis var. parvula | 36 | 65 | 10.10 | 21 | 11 | 3.20 |
| N. sigma (Kuetz.) W. Smith var. sigma | 3 | | 0.30 | 5 | 7 | 1.20 |
| N. *sinuata* var. tabellaria Grun. | 1 | | 0.10 | | | |
| Pinnularia kneuckeri Hust. var kneuckeri | | | | 1 | 1 | 0.20 |
| Rhoicosphenia curvata (Kuetz) Grun. var. curvata | | 1 | 0.10 | 1 | 2 | 0.30 |
| Surirella angusta Kuetz. var. angusta | 2 | 1 | 0.30 | 2 | 2 | 0.40 |
| S. delicatissima Lewis var. delicatissima | | | | | | |
| S. ovalis Breb. var. ovalis | | | | 2 | 1 | 0.30 |
| S. ovata Kuetz. var ovata | | | | | | |
| S. ovata var. pinnata W. Smith | | | | 1 | 3 | 0.40 |
| S. tenera Greg. var. tenera | | | | | | |
| Synedra pulchella Ralfs. ex. Kuetz. var. *pulchella* | | | | 1 | | 0.10 |
| S. ulna (Nitz.) Ehr. var. ulna | 1 | 1 | 0.20 | | | |
| S. ulna var. oxyrhynchus fo. contracta Hust. | | | | 1 | | 0.10 |
| Total number of taxa | 52 | 45 | | 58 | 52 | |
| Total number of individuals | 501 | 499 | | 500 | 500 | |

## APPENDIX XI
## RADFORD ARMY AMMUNITION PLANT

Alphabetical List by Genus and Species of Periphyton Diatoms Collected
From Three Natural Substrates in the New River, Virginia
During November, 1975

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| *Achnanthes clevei* Grun. var. *clevei* | 2 | | 0.20 | | | |
| A. exigua Grun. var. exigua | | | | 1 | | 0.10 |
| A. exigua var. heterovalva Krasske | | | | | | |
| A. lanceolata (Breb.) Grun. var. lanceolata | 2 | 3 | 0.50 | 15 | 6 | 2.10 |
| A. lanceolata var. dubia Grun. | 1 | 3 | 0.40 | 2 | 1 | 0.30 |
| A. linearis var. pusilla Grun. | 48 | 99 | 14.70 | 95 | 49 | 14.40 |
| A. minutissima Kuetz. var. minutissima | 24 | 42 | 6.60 | 28 | 2 | 3.00 |
| Amphiplerua pellucida Kuetz. var. pellucida | | | | | | |
| Amphora ovalis var. pediculus Kuetz. | 3 | 1 | 0.40 | 3 | 13 | 1.60 |
| A. veneta Kuetz. var. veneta var. veneta | | | | | 11 | 1.10 |
| Anomoeoneis serians var. brachysira (Breb. ex Kuetz.) Hust. | | | | | | |
| Caloneis bacillum (Grun.) Cl. var. bacillum | | | | 1 | | 0.10 |
| Cocconeis pediculus Ehr. var. pediculus | | | | | | |
| C. placentula var. euglypta (Ehr.) Cl. | 10 | | 1.00 | 2 | 1 | 0.30 |
| C. placentula var. lineata (Ehr.) V.H. | 9 | 2 | 1.10 | 7 | 2 | 0.90 |
| Cyclotella meneghiniana Kuetz. var. meneghinana | | | | 1 | | 0.10 |
| C. operculata (Ag.) Kuetz. var. operculata | | | | | | |
| C. stelligera Cl. & Grun. var. stelligera | 4 | 8 | 1.20 | 9 | 4 | 1.30 |
| Cymbella affinis Kuetz. var. affinis | | | | | | |
| C. tumida (Breb.) V.H. var. tumida | 6 | 1 | 0.70 | 2 | 4 | 0.60 |
| C. ventricosa Kuetz. var. ventricosa | 5 | 1 | 0.60 | 3 | 1 | 0.40 |
| Denticula tenuris var. crassula (Naegeli) Hust. | | | | | | |
| Diatoma vulgare Bory var. vulgare | 1 | | 0.10 | | | |

| | Station R-5 wood | Station R-5 rock | Station R-5 % dominance | Station R-6 wood | Station R-6 rock | Station R-6 % dominance |
|---|---|---|---|---|---|---|
| Diploneis puella (Schum.) Cl. var. puella | | 1 | 0.10 | 1 | | 0.10 |
| Eunotia g.v. 37.2 μ long, 12 μ wide, 18 striae in 10 | | | | | | |
| E. pectinalis (O. F. Mull.) Rabh. var. pectinalis | 1 | 1 | 0.20 | | | |
| E. vanheurckii var. intermedia (Krasske ex. Hust.) Patr. | | | | 1 | | 0.10 |
| Fragilaria construens (Ehr.) Grun. var. construens | | | | | | |
| F. crotonensis Kitton var. crotonensis | 11 | | 1.10 | 8 | 5 | 1.30 |
| F. crotonensis var. oregona Sov. | | | | 1 | | 0.10 |
| F. leptostauron var. dubia (Grun.) Hust. | | 2 | 0.20 | | | |
| F. pinnata Ehr. var. pinnata | | | | | | |
| F. vaucheriae (Kuetz.) Peters var. vaucheriae | 2 | 2 | 0.40 | 4 | 2 | 0.60 |
| Frustulia asymmetrica (Cl.) Hust. var. asymmetrica | | | | 1 | 1 | 0.20 |
| F. rhomboides var. amphipleuroides (Grun.) Cl. | | | | | | |
| F. rhomboides var. capitata (A. Mayer) Patr. comb. nov. | | | | 2 | | 0.20 |
| F. vulgaris (Thwaites) DeT. var. vulgaris | 3 | | 0.30 | 2 | 1 | 0.30 |
| Gomphonema abbreviatum Ag. Kuetz. var. abbreviatum | | | | | | |
| G. angustatum (Kuetz.) Rahb. var. angustatum | 4 | 3 | 0.70 | 1 | | 0.10 |
| G. augur Ehr. var. augur | | | | | | |
| G. bohemicum Reichelt et Fricke var. bohemicum | | | | 13 | 1 | 1.40 |
| G. olivaceum (Lyngb.) Kuetz. var. olivaceum | | | | | | |
| G. parvulum (Kuetz.) Grun. var. parvulum | | | | 1 | | 0.10 |
| Gyrosigma acuminatum (Kuetz.) Rabh. var. acuminatum | 4 | | 0.40 | 6 | | 0.60 |
| G. exilis (Grun.) Reim. comb. nov., var. exilis | | | | | | |
| G. scalproides (Rabh.) Cl. var. scalproides | 5 | 1 | 0.60 | 3 | 5 | 0.80 |
| Melosira granulata (E.) Ralfs var. granulata | 16 | 6 | 2.20 | 6 | 2 | 0.80 |
| M. granulata var. angustissima Mull. | | | | 2 | | 0.20 |
| M. italica (Ehr.) Kuetz. var. italica | | | | 2 | 1 | 0.30 |
| M. varians C. A. Ag. var. varians | 13 | 2 | 1.50 | 1 | 4 | 0.50 |
| Meridion circulare var. constrictum (Ralfs) V.H. | | 1 | 0.10 | | | |

APPENDIX VII (cont.)

| | Station R-5 wood | Station R-5 rock | Station R-5 % dominance | Station R-6 wood | Station R-6 rock | Station R-6 % dominance |
|---|---|---|---|---|---|---|
| Navicula aikenensis Patr. var. aikenensis | | 2 | 0.20 | 3 | | 0.30 |
| N. arvensis Hust. var arvensis | | 7 | 0.70 | | 1 | 0.10 |
| N. capitata Ehr. var. capitata | | 2 | 0.20 | 2 | 1 | 0.30 |
| N. cincta (Ehr.) Ralfs var. cincta | 28 | 10 | 3.80 | 11 | 31 | 4.20 |
| N. confervacea var. peregrina (W. Sm.) Grun. | | | | | | |
| N. contenta var. biceps (Arn.) V.H. | | 1 | 0.10 | | | |
| N. cryptocephala Kuetz. var. cyptocephala | | | | 5 | | 0.50 |
| N. cryptocephala var. veneta (Kuetz.) Grun. | | | | | | |
| N. decussis Ostr. var. decussis | 1 | 3 | 0.40 | 14 | | 1.40 |
| N. exigua (Gregory) O. Mueller var. exigua | | | | | | |
| N. gregaria Donk var. gregaria | 74 | 29 | 10.30 | 52 | 44 | 9.60 |
| N. gysingensis Foged var. gysingensis | 2 | 4 | 0.60 | | 2 | 0.20 |
| N. heufleri Grun. var. heufleri | 2 | 1 | 0.30 | 2 | | 0.20 |
| N. lanceolata (Ag.) Kuetz. var. lanceolata | 7 | 2 | 0.90 | | 1 | 0.10 |
| N. menisculus var. upsaliensis (Grun.) Grun. | | | | | 1 | 0.10 |
| N. minima Grun. var. minima | 5 | 91 | 9.60 | 16 | 17 | 3.30 |
| N. mutica Kuetz. var. mutica | | | | 1 | | 0.10 |
| N. mutica var. tropica Hust. | 3 | 22 | 2.50 | 1 | | 0.10 |
| N. mutica var. undulata (Hilse) Grun. | 6 | 4 | 1.00 | 1 | 21 | 2.20 |
| N. (c.f. paanaensis A. Cleve-Euler var. paanaensis) | | 2 | 0.20 | 2 | | 0.20 |
| N. pseudoatomus Lund. var. pseudoatomus | 1 | | 0.10 | 1 | | 0.10 |
| N. pupula Kuetz. var. pupula | | 1 | 0.10 | 1 | | 0.10 |
| N. pupula var. capitata Skv. & Meyer | 7 | 1 | 0.80 | 20 | | 2.00 |
| N. pupula var. rectangularis (Greg.) Grun. | | | | | | |
| N. pygmaea Kuetz. var. pygmaea | | | | 1 | | 0.10 |
| N. radiosa var. tenella (Breb. ex Kuetz.) Grun. | 18 | 6 | 2.40 | 20 | 4 | 2.40 |
| N. salinarum var. intermedia (Grun.) Cl. | 10 | 3 | 1.30 | 8 | 1 | 0.90 |
| N. subhamulata Grun. var subhamulata | | 1 | 0.10 | | | |
| N. symmetrica Patr. var symmetrica | 15 | 3 | 1.80 | 4 | 4 | 0.80 |
| N. trip inctata (O. F. Muell.) Bory var tripunctata | 1 | | 0.10 | 1 | | 0.10 |
| N. viridula var. avenacea (Breb. ex Grun.) V.H. | 34 | 3 | 3.70 | 7 | 3 | 1.00 |
| N. viridula var. linearis Hust. | | | | 1 | | 0.10 |
| | | | | | | |
| Neidium dubium (Ehr.) Cl. var. dubium | | | | | | |
| | | | | | | |
| Nitzschia acicularis W. Smith var. acicularis | 5 | 5 | 1.00 | | 1 | 0.10 |
| N. amphibia Grun. var. amphibia | 5 | 29 | 3.40 | 5 | 24 | 2.90 |
| N. clausii Hantzsch var. clausii | 13 | 25 | 3.80 | 1 | 92 | 9.30 |
| N. dissipata (Kuetz.) Grun. var. dissipata | 2 | | 0.20 | 30 | 9 | 3.90 |
| N. fonticola Grun. var. fonticola | 7 | 16 | 2.30 | 5 | 12 | 1.70 |
| N. frustulum (Kuetz.) Grun. var. frustulum | | | | | | |

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | wood | rock | % dominance | wood | rock | % dominance |
| N. hungarica Grun. var. hungarica | | | | | | |
| N. linearis W. Smith var. linearis | 8 | | 0.80 | | 5 | 0.50 |
| N. palea (Kuetz.) W. Smith var. palea | 55 | 33 | 8.80 | 28 | 81 | 10.20 |
| N. parvula Lewis var. parvula | | | | 1 | 10 | 1.11 |
| N. sigma (Kuetz.) W. Smith var. sigma | 3 | | 0.30 | 5 | 2 | 0.70 |
| N. sinuata var. tabellaria Grun. | | 1 | 0.10 | 1 | 1 | 0.20 |
| Pinnularia kneuckeri Hust. var kneuckeri | | | | | | |
| Rhoicosphenia curvata (Kuetz) Grun. var. curvata | 5 | 3 | 0.80 | 33 | 4 | 3.70 |
| Surirella angusta Kuetz. var. angusta | 7 | 3 | 1.00 | 1 | | 0.10 |
| S. delicatissima Lewis var. delicatissima | 1 | | 0.10 | | | |
| S. ovalis Breb. var. ovalis | | 3 | 0.30 | 1 | 1 | 0.20 |
| S. ovata Kuetz. var ovata | 1 | | 0.10 | | | |
| S. ovata var. pinnata W. Smith | | 5 | 0.50 | 1 | | 0.10 |
| S. tenera Greg. var. tenera | | | | 1 | | 0.10 |
| Synedra pulchella Ralfs. ex. Kuetz. var. pulchella | | | | | | |
| S. ulna (Nitz.) Ehr. var. ulna | | | | | | |
| S. ulna var. oxyrhynchus fo. contracta Hust. | | | | | | |
| Total number of taxa | 49 | 49 | | 65 | 45 | |
| Total number of individuals | 500 | 500 | | 511 | 489 | |

## APPENDIX XII

### Taxonomic Keys for the Identification of Benthic Macroinvertebrates


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## APPENDIX XIII

Phylogenetic List of all Benthic Macroinvertebrates Collected from Five Replicate
Artificial Substrates - Rock Baskets. Radford Army Ammunition Plant.
New River, Virginia. May - June 1975

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| NEMATOMORPHA | | | | | | | | | | |
| Gordioidea | | | | | | | | | | |
| Gordiidae | | | | | | | | | | |
| Gordius sp. | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| Tricladia | | | | | | | | | | |
| Planariidae | | | | | | | | | | |
| Dugesia sp. | | | | | | | | | | 3 |
| OLIGOCHEATA | | | | | | | | | | |
| Plesiopora | | | | | | | | | | |
| Tubificidae | | | | | | | | | | |
| Branchiura sowerbyi | | | 1 | | | | | | | |
| Prosopora | | | | | | | | | | |
| Lumbriculidae | | | | | | | | | | |
| Lumbriculus sp. | | | | | | | | | | |
| CRUSTACEA | | | | | | | | | | |
| Isopoda | | | | | | | | | | |
| Asellidae | | | | | | | | | | |
| Asellus sp. | | 2 | 6 | | 4 | | 1 | | | |

APPENDIX XIII Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Amphipoda | | | | | | | | | | |
| Talitridae | | | | | | | | | | |
| *Hyalella azteca* | 25 | 60 | 527 | 46 | 43 | 31 | 8 | 20 | 42 | 34 |
| Gammaridae | | | | | | | | | | |
| *Gammarus* sp. | 1 | 37 | 43 | 13 | 3 | 1 | 1 | 2 | 5 | 2 |
| Decapoda | | | | | | | | | | |
| Astacidae | | 4 | | 5 | 2 | | | | 6 | 1 |
| *Cambarus* sp. | | | | | | | | | | 1 |
| *Orconectes* sp. | | 1 | | 1 | 1 | | | | | |
| INSECTA | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| Ephemeridae | | | | | | | | | | |
| *Ephemera simulans* | | | | | | | | | | |
| *Ephoron leukon* | | | | 4 | | 1 | | 9 | 8 | |
| *Hexagenia atrocaudata* | | | | | | | | | | |
| *H. limbata* | | | | | | | | | | |
| Caenidae | | | | | | | | | | |
| *Caenis* sp. | | 3 | 40 | 4 | | | | | 6 | 7 |
| Ephemerellidae | | | | | | | | | | |
| *Ephemerella* sp. | | | | | | | | | | 7 |
| *E. attenuata* | | | 1 | | | | | | | |
| *E. deficiens* | 67 | 35 | 383 | 87 | 20 | 116 | 131 | 45 | 226 | 247 |
| *E. needhami* | | 1 | | | | | 1 | | | |
| *E. simplex* | | | | | | | | | | 1 |
| *E. tuberculata* | 1 | 4 | 2 | 4 | 1 | 1 | 1 | 1 | | 3 |
| Baetidae | | | | | | | | | | |
| *Baetis* sp. | | | | 4 | | | | | | |
| *Pseudocloeon* sp. | 5 | 4 | 7 | 3 | 5 | 3 | 4 | | 5 | |
| *P. punctiventris* | | 3 | | 1 | | 1 | 1 | 1 | 1 | |

APPENDIX XIII Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Siphlonuridae | | | | | | | | | | |
| Isonychia sp. (1) | 39 | 52 | 541 | 97 | 52 | 82 | 141 | 146 | 321 | 458 |
| I. sp. (2) | 20 | 54 | 79 | 9 | 38 | 36 | 74 | 77 | 68 | 75 |
| Heptageniidae | | | | | | | | | | |
| Heptagenia sp. | | | | | | | | | | |
| Stenonema sp. (femoratum) | 2 | | | 1 | 4 | 1 | 1 | 1 | 2 | |
| Stenonema sp. (interpunctatum) | 15 | 5 | 2 | 2 | 11 | 6 | 3 | 5 | 13 | 7 |
| Stenonema sp. (pulchellum) | 45 | 25 | 49 | 87 | 31 | 21 | 40 | 49 | 52 | 19 |
| Odonata | | | | | | | | | | |
| Libellulidae | | | | | | | | | | |
| Macromia alleghaniensis | 1 | | | | | | | | | |
| Orthemis sp. | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Gomphus fraternus | | | | | | | | | | |
| Ophiogomphus sp. | | | | | | | | | | |
| Lestidae | | | | | | | | | | |
| Lestes sp. | | | | | | | | | | |
| Coenagrionidae | | | | | | | | | | |
| Argia sp. | | | | 2 | 1 | | | | | |
| Chromagrion sp. | | | | | | | | | | |
| Enallagma sp. | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| Pteronarcidae | | | | | | | | | | |
| Pteronarcys sp. | | | | | | | | | | |
| Capniidae | | | | | | | | | | |
| Allocapnia sp. | | 1 | | | | | | | | |
| Perlidae | | | | | | | | | | |
| Neoperla clymene | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Perlesta placida | 3 | 2 | 2 | 6 | | 7 | 4 | 3 | 2 | |
| Phasganophora capitata | | 1 | | | | | 1 | | | |
| Togoperla media | | | | | | | | | | |
| Perlodidae | | | | | | | | | | |
| Isogenus sp. | | | | | | | | | | |
| Megaloptera | | | | | | | | | | |
| Sialidae | | | | | | | | | | |
| Sialis sp. | | | | | | | | | | |
| Corydalidae | | | | | | | | | | |
| Corydalus cornutus | | | | | | | | | 1 | 1 |
| Trichoptera | | | | | | | | | | |
| Hydroptilidae | | | | | | | | | | |
| Agraylea sp. | | | | | | | | | | |
| Neotrichia sp. | | | | | 1 | | | | | |
| Rhyacophilidae | | | | | | | | | | |
| Protoptila sp. | | | | | | | | | | |
| Hydropsychidae | | | | | | | | | | |
| Cheumatopsyche sp. | 69 | 48 | 824 | 183 | 24 | 176 | 247 | 105 | 405 | 545 |
| Hydropsyche sp. | 72 | 15 | 89 | 37 | 18 | 74 | 117 | 24 | 130 | 286 |
| Psychomyiidae | | | | | | | | | | |
| Polycentropus remotus | | | 1 | 3 | 2 | | | 2 | 4 | |
| Leptoceridae | | | | | | | | | | |
| Athripsodes sp. a | | | | | | 1 | | | | |
| A. tarsi-punctatus | | | | | | | | | | |
| Leptocella sp. a | | | | | | | | | | |
| Mystacides sepulchuralis | | | | | | | | | | |
| Oecetis cinerascens | 1 | 1 | 5 | 1 | 2 | 1 | | | 2 | |
| Triaenodes sp. | | | | | | | | | | 2 |
| T. aba | | | | | | | | | | |
| T. injusta | | | | | | | | | | |
| T. tarda | | | | | 3 | | | | | |

APPENDIX XIII Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | | 5 | 1 | 2 | 3 | 4 | 5 |
| Lepidostomatidae | | | | | | | | | | |
| *Lepidostoma* sp. | | | 6 | | 1 | 1 | | | 2 | 3 |
| Brachycentridae | | | | | | | | | | |
| *Micrasema* sp. | | | | | | | 3 | | | |
| Ceoleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| *Acilius* sp. | | | | | | | | | | |
| Elmidae | | | | | | | | | | |
| *Ancyronyx variegata* | | | | | | | | | | |
| *Dubiraphia* sp. | | 3 | | 1 | 4 | | | | | |
| *Gonielmis* sp. | | | 1 | | | | | | | |
| *Optioservus* sp. | | | | | | | 1 | | | 1 |
| *Promoresia* sp. | 3 | 3 | 10 | 1 | | 1 | 1 | | 2 | 3 |
| *Stenelmis* sp. | | | | | | | 1 | | | |
| Diptera | | | | | | | | | | |
| Tipulidae | | | | | | | | | | |
| *Antocha saxicola* | | | | | | | | | | |
| *Tipula* sp. | | | | | | | | | | |
| Simuliidae | | | | | | | | | | |
| *Cnephia* sp. | | | | | | | | | | |
| *Prosimulium* sp. | 6 | 1 | 5 | 6 | | 5 | 9 | | 3 | |
| *Simulium* sp. | | | | | 2 | | | | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* sp. | | | | | | | | | | |
| *Cardiocladius* sp. | | | | | | | | | | |
| *Cladotanytarsus* sp. | 3 | | 46 | 13 | | 18 | 21 | 1 | 28 | |
| *Cricotopus* sp. | 1 | | | | | 13 | 31 | 5 | 1 | |
| *Cryptochironomus* sp. | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| _Dicrotendipes_ sp. | | | 2 | | | | | | | |
| _Endochironomus_ sp. | | 1 | | | | | | | | |
| _Eukiefferiella_ sp. | 1 | | 36 | 14 | | | | | 1 | |
| _Microtendipes_ sp. | | | | | | | | | | |
| _Paratanytarsus_ sp. | | | | | | | | | | |
| _Paratendipes_ sp. | | | | | | | | | | |
| _Pentaneura_ sp. | | | 2 | | | | | 3 | | |
| _Phaenopsectra_ sp. | | 21 | | 1 | 36 | | | | | |
| _Polypedilum_ sp. | 6 | | 17 | 5 | 4 | | | | 27 | |
| _Psectrocladius_ sp. | | | 1 | 1 | | | | | 2 | |
| _Rheotanytarsus_ sp. | | | | | | | | | | |
| _Stictochironomus_ sp. | | 4 | | 9 | | | | | | |
| _Tribelos_ sp. | | | | | | | | | | |
| _Trichocladius_ sp. | | | | | | | | 1 | | |
| Pupae | | | 2 | | | 3 | | | 3 | |
| Ceratopogonidae | | | | | | | | | | |
| _Palpomyia_ sp. | | | | | | | | | | |
| Tabanidae | | | | | | | | | | |
| _Chrysops_ sp. | | | | | | | | | | |
| _Tabanus_ sp. | | | | | | | | | | |
| Empididae | | | | | | | | | | |
| _Hemerodromia_ sp. | | | | | | | | | | |
| GASTROPODA | | | | | | | | | | |
| Pulmonata | | | | | | | | | | |
| Physidae | | | | | | | | | | |
| _Physa_ sp. | 1 | | | | | | | | | |
| Planorbidae | | | | | | | | | | |
| _Gyraulus_ sp. | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Ctenobranchiata | | | | | | | | | | |
| Viviparidae | | | | | | | | | | |
| *Lioplax subcarinata* | 17 | 11 | 15 | 22 | 17 | 18 | 19 | 6 | 9 | 23 |
| PELECYPODA | | | | | | | | | | |
| Sphaeridae | | | | | | | | | | |
| *Pisidium* sp. | | | | | | | 9 | | | |
| *Sphaerium* sp. | | | | | 9 | | | | 1 | |
| TOTAL NUMBER OF TAXA | 23 | 28 | 29 | 32 | 27 | 23 | 26 | 20 | 29 | 22 |
| TOTAL NUMBER OF ORGANISMS | 404 | 402 | 2745 | 673 | 339 | 618 | 871 | 506 | 1378 | 1729 |

## APPENDIX XIII

Phylogenetic List of all Benthic Macroinvertebrates Collected from Five Replicate
Artificial Substrates - Rock Baskets. Radford Army Ammunition Plant.
New River, Virginia. May - June 1975

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| NEMATOMORPHA | | | | | | | | | | |
| Gordioidea | | | | | | | | | | |
| Gordiidae | | | | | | | | | | |
| *Gordius* sp. | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| Tricladia | | | | | | | | | | |
| Planariidae | | | | | | | | | | |
| *Dugesia* sp. | | | | | | | | | | |
| OLIGOCHEATA | | | | | | | | | | |
| Plesiopora | | | | | | | | | | |
| Tubificidae | | | | | 1 | | | | | 1 |
| *Branchiura sowerbyi* | | | | | | | | | | |
| Prosopora | | | | | | | | | | |
| Lumbriculidae | | | | | | | | | | |
| *Lumbriculus* sp. | | | | | | | | | | |

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| CRUSTACEA | | | | | | | | | | |
| Isopoda | | | | | | | | | | |
| Asellidae | | | | | | | | | | |
| *Asellus* sp. | | | | | | | 5 | | 1 | |
| Amphipoda | | | | | | | | | | |
| Talitridae | | | | | | | | | | |
| *Hyalella azteca* | 23 | 24 | 21 | 36 | 78 | 13 | 42 | 22 | 42 | 67 |
| Gammaridae | | | | | | | | | | |
| *Gammarus* sp. | 1 | 17 | 7 | 5 | | 3 | 5 | 7 | 8 | 6 |
| Decapoda | | | | | | | | | | |
| Astacidae | | 1 | 5 | 7 | 5 | 3 | 1 | | 3 | 8 |
| *Cambarus* sp. | | 1 | | | | | | | | |
| *Orconectes* sp. | | | | | | | | | | |
| INSECTA | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| Ephemeridae | | | | | | | | | | |
| *Ephemera simulans* | | | | | | | | | | |
| *Ephoron leukon* | | 12 | 8 | | 2 | | | | 1 | 1 |
| *Hexagenia atrocaudata* | | | | | | | | | | |
| *H. limbata* | | | | | | | | | | |
| Caenidae | | | | | | | | | | |
| *Caenis* sp. | | 58 | 13 | 5 | 6 | 3 | | | 8 | 4 |
| Ephemerellidae | | | | | | | | | | |
| *Ephemerella* sp. | 13 | | | | | | 3 | 1 | | |
| *E. attenuata* | | | | | | | | | | |
| *E. deficiens* | 68 | 21 | 132 | 214 | 206 | 57 | 149 | 114 | 149 | 30 |
| *E. needhami* | | | | | | | | 1 | | |
| *E. simplex* | | | | | | 2 | 2 | | | |
| *E. tuberculata* | | | | 2 | | | 5 | | | |

APPENDIX XIII Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Baetidae | | | | | | | | | | |
| Baetis sp. | | | | | | | | | | |
| Pseudocloeon sp. | | | 1 | 2 | | | 1 | | | |
| P. punctiventris | | | | | | | | | | |
| Siphlonuridae | | | | | | | | | | |
| Isonychia sp. (1) | 59 | 313 | 292 | 306 | 315 | 73 | 68 | 56 | 99 | 47 |
| I. sp. (2) | 17 | 27 | 33 | 49 | 47 | 32 | 50 | 51 | 48 | 20 |
| Heptageniidae | | | | | | | | | | |
| Heptagenia sp. | | | | | | | | | | |
| Stenonema sp. (femoratum) | 4 | 2 | | | 2 | | | | 1 | 8 |
| Stenonema sp. (interpunctatum) | 10 | 52 | 21 | 6 | 37 | 25 | 9 | 34 | 7 | |
| Stenonema sp. (pulchellum) | 26 | 13 | 71 | 40 | 84 | 23 | 35 | 37 | 87 | 80 |
| Odonata | | | | | | | | | | |
| Libellulidae | | | | | | | | | | |
| Macromia alleghaniensis | | | | | | | | | | |
| Orthemis sp. | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Gomphus fraternus | | | | | | | | | | |
| Ophiogomphus sp. | | | | | | | | | | |
| Lestidae | | | | | | | | | | |
| Lestes sp. | | | | | | | | | | |
| Coenagrionidae | | | | | | | | | | |
| Argia sp. | | | 2 | | | 2 | 1 | | | |
| Chromagrion sp. | | | | | | | | | | |
| Enallagma sp. | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| Pteronarcidae | | | | | | | | | | |
| Pteronarcys sp. | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Capniidae | | | | | | | | | | |
| *Allocapnia* sp. | | | | | | | | | | |
| Perlidae | | | | | | | | | | |
| *Neoperla clymene* | | | | | | 1 | | | | |
| *Perlesta placida* | 1 | 1 | 1 | 4 | 6 | 1 | 4 | 1 | 4 | |
| *Phasganophora capitata* | | | | | | | | | | |
| *Togoperla media* | | | | | | | | | | |
| Perlodidae | | | | | | | | | | |
| *Isogenus* sp. | | | | | | | | | | |
| Megaloptera | | | | | | | | | | |
| Sialidae | | | | | | | | | | |
| *Sialis* sp. | | | | | | | | | | |
| Corydalidae | | | | | | | | | | |
| *Corydalus cornutus* | 1 | 1 | | | | | | | 1 | |
| Trichoptera | | | | | | | | | | |
| Hydroptilidae | | | | | | | | | | |
| *Agraylea* sp. | | | | 1 | | | | | | |
| *Neotrichia* sp. | | | | | | | | | | |
| Rhyacophilidae | | | | | | | | | | |
| *Protoptila* sp. | | | | | | | | | | |
| Hydropsychidae | | | | | | | | | | |
| *Cheumatopsyche* sp. | 105 | 27 | 115 | 246 | 267 | 100 | 145 | 209 | 201 | 11 |
| *Hydropsyche* sp. | 63 | 6 | 32 | 135 | 142 | 7 | 8 | 18 | 41 | 4 |
| Psychomyiidae | | | | | | | | | | |
| *Polycentropus remotus* | | | 1 | 1 | | | | | 2 | 4 |
| Leptoceridae | | | | | | | | | | |
| *Athripsodes* sp. a | | | | 2 | 1 | | | | 3 | 4 |
| *A. tarsi-punctatus* | | | | | | | | | | |
| *Leptocella* sp. a | | | | | | | | | | |

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| *Mystacides sepulchuralis* | | | | | 1 | | | | | |
| *Oecetis cinerascens* | | | 3 | 1 | 1 | | | | 1 | |
| *Triaenodes* sp. | | | | | | | | | | |
| *T. aba* | | | | | | | | | | |
| *T. injusta* | | | | | | | 1 | | | |
| *T. tarda* | | | | | | | | 2 | | |
| Lepidostomatidae | | | | | | | | | | |
| *Lepidostoma* sp. | 3 | | | | 1 | 4 | 1 | 2 | | |
| Brachycentridae | | | | | | | | | | |
| *Micrasema* sp. | | | | | | | | | | |
| Ceoleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| *Acilius* sp. | | | | | | | | | | |
| Elmidae | | | | | | | | | | |
| *Ancyronyx variegata* | | | | | | 1 | | 1 | | |
| *Dubiraphia* sp. | | | | 1 | | | 2 | | | |
| *Gonielmis* sp. | | | 1 | | | | | | | |
| *Optioservus* sp. | 1 | | | | | 1 | | 2 | | |
| *Promoresia* sp. | | | | 3 | 4 | | | | | |
| *Stenelmis* sp. | | | | | | | | | | |
| Diptera | | | | | | | | | | |
| Tipulidae | | | | | | | | | | |
| *Antocha saxicola* | | | | | | | 1 | | | |
| *Tipula* sp. | | | | | | | | | | |
| Simuliidae | | | | | | | | | | |
| *Cnephia* sp. | | | | | | | | | | |
| *Prosimulium* sp. | | | | 3 | | | 2 | 6 | 7 | |
| *Simulium* sp. | 2 | | | | 9 | | 1 | | | 1 |

APPENDIX XIII Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* sp. | | | | | | | | | | |
| *Cardiocladius* sp. | | | | | | | | | | |
| *Cladotanytarsus* sp. | | | 20 | 45 | 98 | 8 | 14 | 8 | 20 | 4 |
| *Cricotopus* sp. | | | 1 | 5 | | | | | | |
| *Cryptochironomus* sp. | | | | | | 1 | 11 | | | |
| *Dicrotendipes* sp. | | | | | | | | | | |
| *Endochironomus* sp. | | | | | | | | | | |
| *Eukiefferiella* sp. | | | 14 | 20 | 17 | 1 | | 21 | 6 | 3 |
| *Microtendipes* sp. | | | 1 | | | | | | | |
| *Paratanytarsus* sp. | | | | | | | | | | |
| *Paratendipes* sp. | | | | | | | | | | |
| *Pentaneura* sp. | | | 1 | | | | | | | |
| *Phaenopsectra* sp. | | | | | | | | | | |
| *Polypedilum* sp. | | | | 2 | 3 | 1 | 1 | 3 | 8 | |
| *Psectrocladius* sp. | | | | 3 | 1 | | | | | |
| *Rheotanytarsus* sp. | | | | | | | | | | |
| *Stictochironomus* sp. | | | | | | | | | | |
| *Tribelos* sp. | | | | | | | | | | |
| *Trichocladius* sp. | | | | | | | | | | |
| Pupae | | | 2 | | 3 | 1 | 2 | 3 | | |
| Ceratopogonidae | | | | | | | | | | |
| *Palpomyia* sp. | | | 1 | | | | | | | |
| Tabanidae | | | | | | | | | | |
| *Chrysops* sp. | | | | | | | | | | |
| *Tabanus* sp. | | | | | | | | | | |
| Empididae | | | | | | | | | | |
| *Hemerodromia* sp. | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| GASTROPODA | | | | | | | | | | |
| Pulmonata | | | | | | | | | | |
| Physidae | | | | | | | | | | |
| _Physa_ sp. | | | 1 | | | | | | | |
| Planorbidae | | | | | | | | | | |
| _Gyraulus_ sp. | | | | | | | | 1 | 1 | |
| Ctenobranchiata | | | | | | | | | | |
| Viviparidae | | | | | | | | | | |
| Lioplax subcarinata | 11 | 6 | 9 | 25 | 18 | 12 | 7 | 21 | 13 | 19 |
| PELECYPODA | | | | | | | | | | |
| Sphaeridae | | | | | | | | | | |
| _Pisidium_ sp. | 1 | | 3 | | | | | | | |
| _Sphaerium_ sp. | | | | | | | | | | |
| TOTAL NUMBER OF TAXA | 18 | 17 | 27 | 27 | 25 | 23 | 27 | 22 | 24 | 20 |
| TOTAL NUMBER OF ORGANISMS | 409 | 582 | 812 | 1168 | 1355 | 375 | 576 | 620 | 761 | 323 |

## APPENDIX XIII

**Phylogenetic List of all Benthic Macroinvertebrates Collected from Five Replicate Artificial Substrates - Rock Baskets. Radford Army Ammunition Plant. New River, Virginia. May - June 1975**

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLES COLLECTED | | | | | | | | | |
| NEMATOMORPHA | | | | | | | | | | |
| Gordioidea | | | | | | | | | | |
| Gordiidae | | | | | | | | | | |
| *Gordius* sp. | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| Tricladia | | | | | | | | | | |
| Planariidae | | | | | | | | | | |
| *Dugesia* sp. | | | | | | | | | | |
| OLIGOCHEATA | | | | | | | | | | |
| Plesiopora | | | | | | | | | | |
| Tubificidae | | | | | | | 7 | | | 1 |
| *Branchiura sowerbyi* | | | | | | | | | | |
| Prosopora | | | | | | | | | | |
| Lumbriculidae | | | | | | | | | | |
| *Lumbriculus* sp. | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLES COLLECTED | | | | | | | | | |
| CRUSTACEA | | | | | | | | | | |
| Isopoda | | | | | | | | | | |
| Asellidae | | | | | | | | | | |
| _Asellus_ sp. | | | | | | | | 4 | 1 | |
| Amphipoda | | | | | | | | | | |
| Talitridae | | | | | | | | | | |
| _Hyalella azteca_ | | | | | | 12 | 20 | 29 | 16 | 67 |
| Gammaridae | | | | | | | | | | |
| _Gammarus_ sp. | | | | | | 2 | | 3 | 3 | 6 |
| Decapoda | | | | | | | | | | |
| Astacidae | | | | | | | | 2 | | 8 |
| _Cambarus_ sp. | | | | | | | | | | |
| _Orconectes_ sp. | | | | | | | | | | |
| INSECTA | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| Ephemeridae | | | | | | | | | | |
| _Ephemera simulans_ | | | | | | | | | | |
| _Ephoron leukon_ | | | | | | | 1 | 1 | | 1 |
| _Hexagenia atrocaudata_ | | | | | | | | | | |
| _H. limbata_ | | | | | | | | | | |
| Caenidae | | | | | | | | | | |
| _Caenis_ sp. | | | | | | | | 11 | 10 | 4 |
| Ephemerellidae | | | | | | | | | | |
| _Ephemerella_ sp. | | | | | | | | | | |
| _E. attenuata_ | | | | | | | | | 1 | |
| _E. deficiens_ | | | | | | 72 | 55 | 105 | 32 | 30 |

APPENDIX XIII Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLES COLLECTED | | | | | | | | | |
| E. needhami | | | | | | | | | | |
| E. simplex | | | | | | | | | | |
| E. tuberculata | | | | | | 4 | 4 | 12 | 2 | |
| Baetidae | | | | | | | | | | |
| Baetis sp. | | | | | | | | | | |
| Pseudocloeon sp. | | | | | | | | | | |
| P. punctiventris | | | | | | | | | | |
| Siphlonuridae | | | | | | | | | | |
| Isonychia sp. (1) | | | | | | 43 | 25 | 36 | 38 | 47 |
| I. sp. (2) | | | | | | 36 | 32 | 65 | 19 | 20 |
| Heptageniidae | | | | | | | | | | |
| Heptagenia sp. | | | | | | | | 1 | | |
| Stenonema sp. (femoratum) | | | | | | | | | | |
| Stenonema sp. (interpunctatum) | | | | | | 1 | 1 | | 5 | 8 |
| Stenonema sp. (pulchellum) | | | | | | 19 | 18 | 26 | 29 | 80 |
| Odonata | | | | | | | | | | |
| Libellulidae | | | | | | | | | | |
| Macromia alleghaniensis | | | | | | | | | | |
| Orthemis sp. | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Gomphus fraternus | | | | | | | | | | |
| Ophiogomphus sp. | | | | | | | | | | |
| Lestidae | | | | | | | | | | |
| Lestes sp. | | | | | | | | | | |
| Coenagrionidae | | | | | | | | | | |
| Argia sp. | | | | | | | | | 1 | |
| Chromagrion sp. | | | | | | | | | | |
| Enallagma sp. | | | | | | | | | | |

APPENDIX XIII Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLES COLLECTED | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| Pteronarcidae | | | | | | | | | | |
| *Pteronarcys* sp. | | | | | | | | | | |
| Capniidae | | | | | | | | | | |
| *Allocapnia* sp. | | | | | | | | | | |
| Perlidae | | | | | | | | | | |
| *Neoperla clymene* | | | | | | | | | | |
| *Perlesta placida* | | | | | | | 2 | 2 | | |
| *Phasganophora capitata* | | | | | | | 1 | | | |
| *Togoperla media* | | | | | | | | | | |
| Perlodidae | | | | | | | | | | |
| *Isogenus* sp. | | | | | | | | | | |
| Megaloptera | | | | | | | | | | |
| Sialidae | | | | | | | | | | |
| *Sialis* sp. | | | | | | | | | | |
| Corydalidae | | | | | | | | | | |
| *Corydalus cornutus* | | | | | | 1 | | 1 | 1 | 1 |
| Trichoptera | | | | | | | | | | |
| Hydroptilidae | | | | | | | | | | |
| *Agraylea* sp. | | | | | | | | | | |
| *Neotrichia* sp. | | | | | | | | | | |
| Rhyacophilidae | | | | | | | | | | |
| *Protoptila* sp. | | | | | | | | | | |
| Hydropsychidae | | | | | | | | | | |
| *Cheumatopsyche* sp. | | | | | | 197 | 178 | 99 | 116 | 11 |
| *Hydropsyche* sp. | | | | | | 39 | 44 | 30 | 21 | 4 |

APPENDIX XIII Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLES COLLECTED | | | | | | | | | |
| Psychomyiidae | | | | | | | | | | |
| Polycentropus remotus | | | | | | 3 | 2 | | 1 | 4 |
| Leptoceridae | | | | | | | | | | |
| Athripsodes sp. a | | | | | | 1 | 2 | 1 | | 1 |
| A. tarsi-punctatus | | | | | | | | | | |
| Leptocella sp. a | | | | | | | | | | |
| Mystacides sepulchuralis | | | | | | | | | | |
| Oecetis cinerascens | | | | | | 1 | 2 | | 1 | |
| Triaenodes sp. | | | | | | | | | | |
| T. aba | | | | | | | | | | |
| T. injusta | | | | | | | | | | |
| T. tarda | | | | | | | | | | |
| Lepidostomatidae | | | | | | | | | | |
| Lepidostoma sp. | | | | | | | | 1 | | |
| Brachycentridae | | | | | | | | | | |
| Micrasema sp. | | | | | | | | | | |
| Ceoleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| Acilius sp. | | | | | | | | | | |
| Elmidae | | | | | | | | | | |
| Ancyronyx variegata | | | | | | | | | | |
| Dubiraphia sp. | | | | | | | | | | |
| Gonielmis sp. | | | | | | | | 1 | 2 | |
| Optioservus sp. | | | | | | | | | | |
| Promoresia sp. | | | | | | 1 | 1 | 4 | | 1 |
| Stenelmis sp. | | | | | | | | | | 1 |

APPENDIX XIII Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLES COLLECTED | | | | | | | | | |
| Diptera | | | | | | | | | | |
| Tipulidae | | | | | | | | | | |
| Antocha saxicola | | | | | | | | 1 | | |
| Tipula sp. | | | | | | | | | | |
| Simuliidae | | | | | | | | | | |
| Cnephia sp. | | | | | | | | | | |
| Prosimulium sp. | | | | | | | | | | |
| Simulium sp. | | | | | | 4 | 1 | 2 | 1 | |
| Chironomidae | | | | | | | | | | |
| Ablabesmyia sp. | | | | | | | | | | |
| Cardiocladius sp. | | | | | | | | | | |
| Cladotanytarsus sp. | | | | | | 22 | 12 | 15 | 20 | 9 |
| Cricotopus sp. | | | | | | | | 4 | | |
| Cryptochironomus sp. | | | | | | | | | | |
| Dicrotendipes sp. | | | | | | | | | 16 | |
| Endochironomus sp. | | | | | | | | | | |
| Eukiefferiella sp. | | | | | | 13 | 17 | 39 | 5 | 1 |
| Microtendipes sp. | | | | | | | | | | |
| Paratanytarsus sp. | | | | | | | | | | |
| Paratendipes sp. | | | | | | | | | | |
| Pentaneura sp. | | | | | | | | | 3 | |
| Phaenopsectra sp. | | | | | | | | | | |
| Polypedilum sp. | | | | | | 6 | 11 | 9 | 2 | |
| Psectrocladius sp. | | | | | | | | | | 3 |
| Rheotanytarsus sp. | | | | | | | 38 | | | |
| Stictochironomus sp. | | | | | | | | | | |
| Tribelos sp. | | | | | | | | | | 7 |
| Trichocladius sp. | | | | | | | | 1 | | |
| Pupae | | | | | | 5 | 6 | 1 | 4 | 4 |

APPENDIX XIII Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | NO SAMPLE COLLECTED | | | | | | | | | |
| Ceratopogonidae | | | | | | | | | | |
| *Palpomyia* sp. | | | | | | | | | | |
| Tabanidae | | | | | | | | | | |
| *Chrysops* sp. | | | | | | | | | | |
| *Tabanus* sp. | | | | | | | | | | |
| Empididae | | | | | | | | | | |
| *Hemerodromia* sp. | | | | | | | 1 | | | |
| GASTROPODA | | | | | | | | | | |
| Pulmonata | | | | | | | | | | |
| Physidae | | | | | | | | | | |
| *Physa* sp. | | | | | | | | | | |
| *Planorbidae* | | | | | | | | | | |
| *Gyraulus* sp. | | | | | | | | | | |
| Ctenobranchiata | | | | | | | | | | |
| Viviparidae | | | | | | | | | | |
| *Lioplax subcarinata* | | | | | | 45 | 31 | 22 | 8 | 26 |
| PELECYPODA | | | | | | | | | | |
| Sphaeridae | | | | | | | | | | |
| *Pisidium* sp. | | | | | | | | | | |
| *Sphaerium* sp. | | | | | | | | | | 1 |
| TOTAL NUMBER OF TAXA | | | | | | 20 | 24 | 28 | 25 | 24 |
| TOTAL NUMBER OF ORGANISMS | | | | | | 527 | 512 | 528 | 358 | 346 |

## APPENDIX XIV

**Phylogenetic List of all Benthic Macroinvertebrates Collected from Five Replicate Natural Substrates - Kick Method. Radford Army Ammunition Plant. New River, Virginia. May - June 1975**

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| NEMATOMORPHA | | | 1 | 1 | | | | | | |
| Gordioidea | | | | | | | | | | |
| Gordiidae | | | | | | | | | | |
| Gordius sp. | | | | | | | | 2 | | 1 |
| *TURBELLARIA* | | | | | | | | | | |
| Tricladia | | | | | | | | | | |
| Planariidae | | | | | | | | | | |
| Dugesia sp. | | | 1 | 1 | | 2 | | | | |
| OLIGOCHEATA | | | | | | | | | | |
| Plesiopora | | | | | | | | | | |
| Tubificidae | | | | | | 6 | | | 8 | |
| Branchiura sowerbyi | | | | 5 | 3 | | | | | |
| Prosopora | | | | | | | | | | |
| Lumbriculidae | | | | | | | | | | |
| Lumbriculus sp. | | | 1 | 3 | | 14 | | 1 | | |
| CRUSTACEA | | | | | | | | | | |
| Isopoda | | | | | | | | | | |
| Asellidae | | | | | | | | | | |
| Asellus sp. | | 2 | 2 | 2 | | | | 4 | | |

APPENDIX XIV Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Amphipoda | | | | | | | | | | |
| Talitridae | | | | | | | | | | |
| *Hyalella azteca* | 208 | 350 | 243 | 146 | 123 | 129 | 67 | 132 | 88 | 20 |
| Gammaridae | | | | | | | | | | |
| *Gammarus* sp. | 1 | 5 | 12 | 8 | 4 | 2 | | 9 | | 2 |
| Decapoda | | | | | | | | | | |
| Astacidae | | 2 | | | 1 | | 6 | | | |
| *Cambarus* sp. | | | 1 | | 1 | 1 | | | | |
| *Orconectes* sp. | | | 2 | | 2 | | | 1 | | |
| INSECTA | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| Ephemeridae | | | | | | | | | | |
| *Ephemera simulans* | 2 | 1 | 7 | 1 | | | | | 2 | |
| *Ephoron leukon* | | | | | | | | | | |
| *Hexagenia atrocaudata* | | | | | | | | | | |
| *H. limbata* | | | | | | | 1 | | | |
| Caenidae | | | | | | | | | | |
| *Caenis* sp. | | | | | | | | | | |
| Ephemerellidae | | | | | | | | | | |
| *Ephemerella* sp. | 2 | 7 | 3 | 11 | 1 | 2 | 2 | 8 | | 6 |
| *E. attenuata* | | | | | | | | | | |
| *E. deficiens* | 46 | 84 | 56 | 291 | 50 | 39 | 140 | 140 | 65 | 45 |
| *E. needhami* | 161 | 158 | 135 | 254 | 66 | 126 | 184 | 153 | 94 | 115 |
| *E. simplex* | | | | | | | | | | |
| *E. tuberculata* | | 7 | 5 | 55 | 4 | | 9 | 8 | 1 | 11 |
| Baetidae | | | | | | | | | | |
| *Baetis* sp. | | | | | | | | | | |
| *Pseudocloeon* sp. | 4 | 14 | 10 | 2 | 2 | 5 | 4 | 4 | | |
| *P. punctiventris* | 4 | | 7 | 3 | 3 | 2 | 2 | 5 | 6 | 1 |
| Siphlonuridae | | | | | | | | | | |
| *Isonychia* sp. (1) | 1 | | | | | 2 | 2 | | | |
| *I.* sp. (2) | | | 1 | | 2 | | 1 | 10 | | 1 |

APPENDIX XIV Cont.

| Replicates | Station R-1 1 | 2 | 3 | 4 | 5 | Station R-2 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|
| Heptageniidae | | | | | | | | | | |
| Heptagenia sp. | | | | | | | | | | |
| Stenonema sp. (femoratum) | | | 2 | 8 | 4 | | 1 | 1 | 2 | |
| Stenonema sp. (interpunctatum) | 3 | | 5 | 2 | 2 | | 2 | | | |
| Stenonema sp. (pulchellum) | 20 | 74 | 44 | 13 | 51 | 13 | 64 | 81 | 12 | 7 |
| Odonata | | | | | | | | | | |
| Libellulidae | | | | | | | | | | |
| Macromia alleghaniensis | | | | | | | | 1 | 1 | |
| Orthemis sp. | | | 1 | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Gomphus fraternus | | | | | | | | | | |
| Ophiogomphus sp. | | | | | 1 | | | | | |
| Lestidae | | | | | | | | | | |
| Lestes sp. | | 2 | | | 1 | | | | | |
| Coenagrionidae | | | | | | | | | | |
| Argia sp. | | 1 | | | 1 | | | | | |
| Chromagrion sp. | 2 | | | | | | 1 | | | |
| Enallagma sp. | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| Pteronarcidae | | | | | | | | | | |
| Pteronarcys sp. | | | | 1 | | | 1 | | | |
| Capniidae | | | | | | | | | | |
| Allocapnia sp. | | | | | | | | | | |
| Perlidae | | | | | | | | | | |
| Neoperla clymene | | | | 2 | 1 | | | | | |
| Perlesta placida | | | | 2 | | | 1 | 1 | 1 | |
| Phasganophora capitata | | | | 2 | | | | | | |
| Togoperla media | | | | | | | | | | |

APPENDIX XIV Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Perlodidae | | | | | | | | | | |
| Isogenus sp. | | | | | | | | | | |
| Megaloptera | | | | | | | | | | |
| Sialidae | | | | | | | | | | |
| Sialis sp. | | | | | | | | | | |
| Corydalidae | | | | | | | | | | |
| Corydalus cornutus | | | | | | | | | | |
| Trichoptera | | | | | | | | | | |
| Hydroptilidae | | | | | | | | | | |
| Agraylea sp. | | | | 5 | | 2 | 1 | | | 1 |
| Neotrichia sp. | | | | | | | | | | |
| Rhyacophilidae | | | | | | | | | | |
| Protoptila sp. | | | | | 1 | | | | | |
| Hydropsychidae | | | | | | | | | | |
| Cheumatopsyche sp. | 3 | 2 | 2 | 16 | 1 | | 3 | 6 | 1 | 1 |
| Hydropsyche sp. | 25 | 27 | 36 | 103 | 33 | 33 | 48 | 90 | 34 | 30 |
| Psychomyiidae | | | | | | | | | | |
| Polycentropus remotus | 1 | 5 | 1 | | 1 | 1 | 2 | 2 | 1 | 1 |
| Leptoceridae | | | | | | | | | | |
| Athripsodes sp. a | | | | | | | | | | |
| A. tarsi-punctatus | | | 1 | | | 1 | | | | |
| Leptocella sp. a | | | 1 | | | 3 | 1 | 3 | | 1 |
| Mystacides sepulchuralis | | | 1 | | | | 1 | | | |
| Oecetis cinerascens | | 7 | 5 | 2 | 1 | 3 | 8 | 6 | 3 | 1 |
| Triaenodes sp. | | | | | | | | | | |
| T. aba | | | | | | | | | | |
| T. injusta | 3 | | 4 | | 1 | 1 | 1 | | 1 | 1 |
| T. tarda | 5 | 14 | 18 | 5 | 1 | 1 | 4 | 6 | | 7 |
| Lepidostomatidae | | | | | | | | | | |
| Lepidostoma sp. | 14 | 60 | 27 | 390 | 7 | 27 | 42 | 69 | 18 | 44 |

APPENDIX XIV Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Brachycentridae | | | | | | | | | | |
| *Micrasema* sp. | | 3 | 3 | 3 | 1 | 1 | 1 | 5 | 1 | 4 |
| Ceoleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| *Acilius* sp. | | | | | | | | | | |
| Elmidae | | | | | | | | | | |
| *Ancyronyx variegata* | | | | | | | | | | |
| *Dubiraphia* sp. | 4 | | 5 | 1 | | 1 | 1 | | | |
| *Gonielmis* sp. | | | | | | | | | | |
| *Optioservus* sp. | 3 | 13 | 2 | 5 | 1 | | | 1 | 1 | 1 |
| *Promoresia* sp. | 3 | | | 19 | 3 | 4 | 10 | 6 | 6 | 10 |
| *Stenelmis* sp. | 1 | | | | 1 | | | | | |
| Diptera | | | | | | | | | | |
| Tipulidae | | | | | | | | | | |
| *Antocha saxicola* | | | | | | | | | | |
| *Tipula* sp. | | | | | | | | | | |
| Simuliidae | | | | | | | | | | |
| *Cnephia* sp. | | | | | | | | | | |
| *Prosimulium* sp. | | | 1 | 4 | | | | 1 | | 2 |
| *Simulium* sp. | | | | 3 | | | 2 | | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* sp. | | | | | | | | | | |
| *Cardiocladius* sp. | | | 1 | 4 | | | | | | |
| *Cladotanytarsus* sp. | 2 | 1 | 6 | 62 | 12 | 29 | 12 | 3 | 14 | 10 |
| *Cricotopus* sp. | | | | | | | | 2 | 2 | 3 |
| *Cryptochironomus* sp. | | | 1 | | | 2 | | | 1 | |
| *Dicrotendipes* sp. | | | | | | | | | | |
| *Endochironomus* sp. | | | | | | | | | | |
| *Eukiefferiella* sp. | 1 | 1 | 1 | 16 | 1 | 2 | 3 | 1 | 5 | |

APPENDIX XIV Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| *Microtendipes* sp. | | | | | | | | | | |
| *Paratanytarsus* sp. | | | | | | | | | | |
| *Paratendipes* sp. | 1 | | | | | | | | | |
| *Pentaneura* sp. | 1 | | | | | | 1 | | | |
| *Phaenopsectra* sp. | | | | | | | | | | |
| *Polypedilum* sp. | 1 | | 1 | 5 | | 3 | 3 | | 3 | |
| *Psectrocladius* sp. | | | | | 2 | | 1 | | | |
| *Rheotanytarsus* sp. | | | | | | | | | | |
| *Stictochironomus* sp. | | | | | | 6 | | | | |
| *Tribelos* sp. | | | | | | | | | | |
| *Trichocladius* sp. | | | | | | | | | | |
| Pupae | 1 | | | | | 8 | | | 3 | |
| Ceratopogonidae | | | | | | | | | | |
| *Palpomyia* sp. | | | | | | | | | | 1 |
| Tabanidae | | | | | | | | | | |
| *Chrysops* sp. | | | | | | | | | 1 | |
| *Tabanus* sp. | | | | | | | | | | |
| Empididae | | | | | | | | | | |
| *Hemerodromia* sp. | | 1 | 1 | | | | | | | |
| GASTROPODA | | | | | | | | | | |
| Pulmonata | | | | | | | | | | |
| Physidae | | | | | | | | | | |
| *Physa* sp. | 8 | | 4 | 7 | 3 | 3 | 1 | 14 | 1 | 18 |
| Planorbidae | | | | | | | | | | |
| *Gyraulus* sp. | | | | 1 | | | | | | |
| Ctenobranchiata | | | | | | | | | | |
| Viviparidae | | | | | | | | | | |
| *Lioplax subcarinata* | 4 | 38 | 1 | 32 | 3 | 1 | 1 | 1 | 1 | 1 |

APPENDIX XIV Cont.

| | Station R-1 | | | | | Station R-2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| PELECYPODA | | | | | | | | | | |
| Sphaeridae | | | | | | | | | | |
| *Pisidium* sp. | | | 7 | 66 | 4 | | | 11 | | 35 |
| *Sphaerium* sp. | 3 | 4 | 2 | 62 | 2 | 9 | 4 | 2 | | 2 |
| TOTAL NUMBER OF TAXA | 30 | 26 | 45 | 41 | 39 | 32 | 39 | 35 | 28 | 30 |
| TOTAL NUMBER OF ORGANISMS | 546 | 883 | 672 | 1623 | 402 | 483 | 639 | 790 | 377 | 384 |

APPENDIX XIV

Phylogenetic List of all Benthic Macroinvertebrates Collected from Five Replicate
Natural Substrates - Kick Method. Radford Army Ammunition Plant.
New River, Virginia. May - June 1975

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| NEMATOMORPHA | | | | | | | | | | |
| Gordioidea | | | | | | | | | | |
| Gordiidae | | | | | | | | | | |
| <u>Gordius</u> sp. | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| Tricladia | | | | | | | | | | |
| Planariidae | | | | | | | | | | |
| <u>Dugesia</u> sp. | | | | | | | | | | |
| OLIGOCHEATA | | | | | | | | | | |
| Plesiopora | | | | | | | | | | |
| Tubificidae | | 2 | | | | | | | | |
| <u>Branchiura sowerbyi</u> | | | 4 | 1 | | 5 | 14 | 3 | 1 | |
| Prosopora | | | | | | | | | | |
| Lumbriculidae | | | | | | | | | | |
| <u>Lumbriculus</u> sp. | | | | | 3 | | 5 | 10 | | |
| CRUSTACEA | | | | | | | | | | |
| Isopoda | | | | | | | | | | |
| Asellidae | | | | | | | | | | |
| <u>Asellus</u> sp. | 1 | 1 | 2 | 1 | 1 | 22 | 17 | 3 | 6 | 6 |

APPENDIX XIV Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Amphipoda | | | | | | | | | | |
| Talitridae | | | | | | | | | | |
| *Hyalella azteca* | 109 | 175 | 40 | 74 | 40 | 12 | 10 | 9 | 3 | 13 |
| Gammaridae | | | | | | | | | | |
| *Gammarus* sp. | 5 | 3 | | 1 | 1 | 12 | 8 | 6 | 3 | 9 |
| Decapoda | | | | | | | | | | |
| Astacidae | | | | | | | | | | |
| *Cambarus* sp. | | | | | | | 1 | | | |
| *Orconectes* sp. | | | | | | 1 | | | | |
| INSECTA | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| Ephemeridae | | | | | | | | | | |
| *Ephemera simulans* | | 32 | | | | 4 | | | 2 | 1 |
| *Ephoron leukon* | | | | | | | | | | |
| *Hexagenia atrocaudata* | | | | | | 1 | | | | |
| *H. limbata* | | | | | | | | 1 | | |
| Caenidae | | | | | | | | | | |
| *Caenis* sp. | | | | | | | | | | |
| Ephemerellidae | | | | | | | | | | |
| *Ephemerella* sp. | 1 | | 1 | 3 | | | | | | |
| *E. attenuata* | | | | | | | | | | |
| *E. deficiens* | 16 | 32 | 26 | 38 | 34 | | 1 | | | |
| *E. needhami* | 17 | 37 | 53 | 74 | 39 | 1 | | 2 | | 2 |
| *E. simplex* | | | | 1 | | 3 | 3 | 1 | 2 | 3 |
| *E. tuberculata* | | 3 | 5 | | | | | | | |
| Baetidae | | | | | | | | | | |
| *Baetis* sp. | | | | | | | | | | |
| *Pseudocloeon* sp. | 12 | | 6 | 5 | | | | | | |
| *P. punctiventris* | | | | | 1 | | | | | |

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Siphlonuridae | | | | | | | | | | |
| *Isonychia* sp. (1) | | | | | | | | | | |
| *I.* sp. (2) | | 1 | 1 | | | | | | | 2 |
| Heptageniidae | | | | | | | | | | |
| *Heptagenia* sp. | | | | | | | | | | |
| *Stenonema* sp. (femoratum) | 1 | 1 | | | | 3 | 4 | | 1 | 4 |
| *Stenonema* sp. (interpunctatum) | 34 | 10 | 1 | | 7 | 1 | 7 | 2 | 16 | 110 |
| *Stenonema* sp. (pulchellum) | 21 | 31 | 27 | 8 | 4 | 45 | 23 | 16 | 29 | 48 |
| Odonata | | | | | | | | | | |
| Libellulidae | | | | | | | | | | |
| *Macromia alleghaniensis* | | 1 | | | | | | | | |
| *Orthemis* sp. | | | 1 | | | | | | | |
| Gomphidae | | | | | | | | | | |
| *Gomphus fraternus* | | | | | | | | | | |
| *Ophiogomphus* sp. | | | | | | | | | | |
| Lestidae | | | | | | | | | | |
| *Lestes* sp. | | | | | | | | | | |
| Coenagrionidae | | | | | | | | | | |
| *Argia* sp. | | | | | | | 1 | | | 4 |
| *Chromagrion* sp. | | 1 | 1 | | | | | | | |
| *Enallagma* sp. | | | | | | | | | | |
| Plecoptera | | | | | | | | | | |
| Pteronarcidae | | | | | | | | | | |
| *Pteronarcys* sp. | | | | | 1 | | | | | |
| Capniidae | | | | | | | | | | |
| *Allocapnia* sp. | | | | | | | | | | |
| Perlidae | | | | | | | | | | |
| *Neoperla clymene* | | | | | | | | | | 1 |

APPENDIX XIV Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| *Perlesta placida* | | | | | | 1 | | | | |
| *Phasganophora capitata* | | | | | | | | | | |
| *Togoperla media* | | | | | | 2 | | | | |
| Perlodidae | | | | | | | | | | |
| *Isogenus* sp. | | | | | | | | | | |
| Megaloptera | | | | | | | | | | |
| Sialidae | | | | | | | | | | |
| *Sialis* sp. | | | | | | | | | | 1 |
| Corydalidae | | | | | | | | | | |
| *Corydalus cornutus* | | | | | | | | | | |
| Trichoptera | | | | | | | | | | |
| Hydroptilidae | | | | | | | | | | |
| *Agraylea* sp. | | | | 4 | 4 | 4 | 1 | 1 | 1 | |
| *Neotrichia* sp. | | | | | | | | | | |
| Rhyacophilidae | | | | | | | | | | |
| *Protoptila* sp. | | | | | | | | | | |
| Hydropsychidae | | | | | | | | | | |
| *Cheumatopsyche* sp. | | 1 | 2 | 5 | 3 | | | 1 | | |
| *Hydropsyche* sp. | 2 | 14 | 10 | 11 | 24 | | | 1 | | |
| Psychomyiidae | | | | | | | | | | |
| *Polycentropus remotus* | 1 | 1 | | 1 | | 9 | 8 | 8 | 2 | 1 |
| Leptoceridae | | | | | | | | | | |
| *Athripsodes* sp. a | | | | | | | | | | |
| *A. tarsi-punctatus* | | | | | | | | | | |
| *Leptocella* sp. a | 2 | | | 1 | 1 | | | | | |
| *Mystacides sepulchuralis* | | | 4 | | | | | | | |
| *Oecetis cinerascens* | | 3 | 5 | | 1 | | | | | |
| *Triaenodes* sp. | | | | 1 | | | | | | |
| *T. aba* | 2 | | | | 1 | | | | | |
| *T. injusta* | 3 | 4 | | 2 | | | | | | |
| *T. tarda* | 4 | 10 | 7 | 4 | 1 | | | | | 1 |

APPENDIX XIV Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| Lepidostomatidae | 5 | 10 | 14 | 9 | 17 | | | | | |
| *Lepidostoma* sp. | | | | | | 1 | | | | 3 |
| Brachycentridae | | 2 | | | | | | | | |
| *Micrasema* sp. | | | | | | | | | | |
| Caoleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| *Acilius* sp. | | | | | | 1 | | | | |
| Elmidae | | | | | | | | | | |
| *Ancyronyx variegata* | | | | | | | | | | |
| *Dubiraphia* sp. | | 1 | 1 | | | 1 | | 2 | 1 | |
| *Gonielmis* sp. | | | | | | | | | | |
| *Optioservus* sp. | 4 | 1 | 1 | 5 | | | | | | |
| *Promoresia* sp. | | 6 | 4 | 4 | 3 | | | | | |
| *Stenelmis* sp. | | | | | | | | | | |
| Diptera | | | | | | | | | | |
| Tipulidae | | | | | | | | | | |
| *Antocha saxicola* | | | | | | | | | | |
| *Tipula* sp. | | | | | | | | | | |
| Simuliidae | | | | | | | | | | |
| *Cnephia* sp. | | | | 1 | | | | | | |
| *Prosimulium* sp. | | | | | | | 1 | | | |
| *Simulium* sp. | | 1 | | | | | | | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* sp. | | | | | | 1 | 3 | | 1 | |
| *Cardiocladius* sp. | | | | | | | | | 4 | |
| *Cladotanytarsus* sp. | | 1 | 6 | 27 | 1 | 5 | 8 | 6 | | |
| *Cricotopus* sp. | | | | | | 39 | 64 | 43 | 18 | 16 |
| *Cryptochironomus* sp. | | | 1 | | | | | 1 | | |
| *Dicrotendipes* sp. | | | | | | | | | | |
| *Endochironomus* sp. | | | | | | | 4 | | | |

APPENDIX XIV Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| *Eukiefferiella* sp. | 2 | | 2 | 3 | 1 | | | 1 | | |
| *Microtendipes* sp. | | | | | | | | | | |
| *Paratanytarsus* sp. | | | | | | | | | | |
| *Paratendipes* sp. | | | | | | | | 5 | | |
| *Pentaneura* sp. | | | | | | | 3 | 4 | | 1 |
| *Phaenopsectra* sp. | | | | | | | | | | |
| *Polypedilum* sp. | | | 4 | 3 | | 1 | | 1 | | |
| *Psectrocladius* sp. | | | 1 | | | | | | | |
| *Rheotanytarsus* sp. | 2 | | | | | 1 | | | 4 | |
| *Stictochironomus* sp. | | | | | | | | | | |
| *Tribelos* sp. | | | | | | | | | | |
| *Trichocladius* sp. | 1 | | | | | | | | | |
| Pupae | | | 1 | | 1 | | 3 | 1 | | |
| Ceratopogonidae | | | | | | | | | | |
| *Palpomyia* sp. | | | | | | | | | | |
| Tabanidae | | | | | | | | | | |
| *Chrysops* sp. | | | | | | | | | | |
| *Tabanus* sp. | | | | | | | | | | 1 |
| Empididae | | | | | | | | | | |
| *Hemerodromia* sp. | | | | | | | | | | |
| GASTROPODA | | | | 1 | | | | | | |
| Pulmonata | | | | | | | | | | |
| Physidae | | | | | | | | | | |
| *Physa* sp. | | 1 | 2 | | | | | | | |
| Planorbidae | | | | | | | | | | |
| *Gyraulus* sp. | | | | | | | | | | |
| Ctenobranchiata | | | | | | | | | | |
| Viviparidae | | | | | | | | | | |
| *Lioplax subcarinata* | | 2 | 1 | | | | | | | |

APPENDIX XIV Cont.

| | Station R-3 | | | | | Station R-4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| PELECYPODA | | | | | | | | | | |
| Sphaeridae | | | | | | | | | | |
| *Pisidium* sp. | 2 | 1 | 3 | 4 | 3 | 4 | 2 | | 1 | |
| *Sphaerium* sp. | 1 | 3 | | 1 | 2 | 2 | 2 | | | |
| TOTAL NUMBER OF TAXA | 23 | 31 | 31 | 27 | 23 | 26 | 21 | 23 | 17 | 19 |
| TOTAL NUMBER OF ORGANISMS | 248 | 392 | 238 | 292 | 194 | 182 | 189 | 132 | 94 | 227 |

## APPENDIX XIV

**Phylogenetic List of all Benthic Macroinvertebrates Collected from Five Replicate Natural Substrates - Kick Method. Radford Army Ammunition Plant. New River, Virginia. May - June 1975**

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| NEMATOMORPHA | | | | | | | | 4 | | |
| Gordioidea | | | | | | | | | | |
| Gordiidae | | | | | | | | | | |
| *Gordius* sp. | | | | | | | | | | |
| TURBELLARIA | | | | | | | | | | |
| Tricladia | | | | | | | | | | |
| Planariidae | | | | | | | | | | |
| *Dugesia* sp. | | | | | | 1 | | 2 | | |
| OLIGOCHEATA | | | | | | | | | | |
| Plesiopora | | | | | | | | | | |
| Tubificidae | | | | | | | 8 | | | |
| *Branchiura sowerbyi* | | | | | | | | | 2 | |
| Prosopora | | | | | | | | | | |
| Lumbriculidae | | | | | | | | | | |
| *Lumbriculus* sp. | | | | | | | | | | |
| CRUSTACEA | | | | | | | | | | |
| Isopoda | | | | | | | | | | |
| Asellidae | | | | | | | | | | |
| *Asellus* sp. | | | | | | | 1 | | | |

APPENDIX XIV Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| Amphipoda | | | | | | | | | | |
| Talitridae | | | | | | | | | | |
| Hyalella azteca | | | | | | 20 | 34 | 77 | 49 | 31 |
| Gammaridae | | | | | | | | | | |
| Gammarus sp. | | | | | | | | 7 | 3 | |
| Decapoda | | | | | | | | | | |
| Astacidae | | | | | | | | | | |
| Cambarus sp. | | | | | | | 1 | | | |
| Orconectes sp. | | | | | | | | | | |
| INSECTA | | | | | | | | | | |
| Ephemeroptera | | | | | | | | | | |
| Ephemeridae | | | | | | | | | | |
| Ephemera simulans | | | | | | | | | | |
| Ephoron leukon | | | | | | | | | | |
| Hexagenia atrocaudata | | | | | | | | | | |
| H. limbata | | | | | | | | | | |
| Caenidae | | | | | | | | | | |
| Caenis sp. | | | | | | | | | | |
| Ephemerellidae | | | | | | | | | | |
| Ephemerella sp. | | | | | | | 1 | 1 | | 4 |
| E. attenuata | | | | | | | | | | |
| E. deficiens | | | | | | 18 | 19 | 48 | 18 | 35 |
| E. needhami | | | | | | 19 | 26 | 35 | 28 | 34 |
| E. simplex | | | | | | | | | | |
| E. tuberculata | | | | | | | 1 | 12 | 1 | 3 |
| Baetidae | | | | | | | | | | |
| Baetis sp. | | | | | | | | 1 | | |
| Pseudocloeon sp. | | | | | | 14 | 23 | 24 | 8 | 26 |
| P. punctiventris | | | | | | | 5 | | | |

APPENDIX XIV Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| Siphlonuridae | | | | | | | | | | |
| Isonychia sp. (1) | | | | | | 1 | | 3 | 2 | |
| I. sp. (2) | | | | | | | | | | |
| Heptageniidae | | | | | | | | | | |
| Heptagenia sp. | | | | | | | | | | |
| Stenonema sp. (femoratum) | | | | | | 3 | | | 4 | |
| Stenonema sp. (interpunctatum) | | | | | | 3 | 3 | | 6 | |
| Stenonema sp. (pulchellum) | | | | | | 21 | 5 | 11 | 14 | 8 |
| Odonata | | | | | | | | | | |
| Libellulidae | | | | | | | | | | |
| Macromia alleghaniensis | | | | | | | | | | 1 |
| Orthemis sp. | | | | | | | | | | |
| Gomphidae | | | | | | | | | | |
| Gomphus fraternus | | | | | | | | | | |
| Ophiogomphus sp. | | | | | | | | | | |
| Lestidae | | | | | | | | | | |
| Lestes sp. | | | | | | | | | | |
| Coenagrionidae | | | | | | | | | | |
| Argia sp. | | | | | | | | | | |
| Chromagrion sp. | | | | | | | | | | |
| Enallagma sp. | | | | | | | | 1 | | |
| Plecoptera | | | | | | | | | | |
| Pteronarcidae | | | | | | | | | | |
| Pteronarcys sp. | | | | | | | | | | 1 |
| Capniidae | | | | | | | | | | |
| Allocapnia sp. | | | | | | | | | | |
| Perlidae | | | | | | | | | | |
| Neoperla clymene | | | | | | 1 | | | | |
| Perlesta placida | | | | | | | | | | |

APPENDIX XIV Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| Phasganophora capitata | | | | | | | | | | |
| Togoperla media | | | | | | | | | | |
| Perlodidae | | | | | | | | | | |
| Isogenus sp. | | | | | | 1 | | | | 1 |
| Megaloptera | | | | | | | | | | |
| Sialidae | | | | | | | | | | |
| Sialis sp. | | | | | | | | | | |
| Corydalidae | | | | | | | | | | |
| Corydalus cornutus | | | | | | | | | | |
| Trichoptera | | | | | | | | | | |
| Hydroptilidae | | | | | | | | | | |
| Agraylea sp. | | | | | | 1 | | 1 | | |
| Neotrichia sp. | | | | | | | | | 1 | |
| Rhyacophilidae | | | | | | | | | | |
| Protoptila sp. | | | | | | 1 | | | | |
| Hydropsychidae | | | | | | | | | | |
| Cheumatopsyche sp. | | | | | | 1 | 1 | | | |
| Hydropsyche sp. | | | | | | 4 | 1 | 12 | 2 | 25 |
| Psychomyiidae | | | | | | | | | | |
| Polycentropus remotus | | | | | | | | | | |
| Leptoceridae | | | | | | | | | | |
| Athripsodes sp. a | | | | | | | | | | |
| A. tarsi-punctatus | | | | | | | | | | |
| Leptocella sp. a | | | | | | | | 1 | | |
| Mystacides sepulchuralis | | | | | | | | | | 1 |
| Oecetis cinerascens | | | | | | | | 2 | | 5 |
| Triaenodes sp. | | | | | | | | | | 1 |
| T. aba | | | | | | | | | | |
| T. injusta | | | | | | 9 | 1 | 5 | 9 | |
| T. tarda | | | | | | 7 | 14 | 20 | 13 | 7 |

APPENDIX XIV Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| Lepidostomatidae | | | | | | | | | | |
| *Lepidostoma* sp. | | | | | | 1 | 3 | 9 | 3 | 2 |
| Brachycentridae | | | | | | | | | | |
| *Micrasema* sp. | | | | | | 1 | | 2 | | 3 |
| Ceoleoptera | | | | | | | | | | |
| Dytiscidae | | | | | | | | | | |
| *Acilius* sp. | | | | | | | | | | |
| Elmidae | | | | | | | | | | |
| *Ancyronyx variegata* | | | | | | | | | | |
| *Dubiraphia* sp. | | | | | | | | 1 | | |
| *Gonielmis* sp. | | | | | | | | | | |
| *Optioservus* sp. | | | | | | 1 | 2 | 3 | | 1 |
| *Promoresia* sp. | | | | | | | 3 | | | 3 |
| *Stenelmis* sp. | | | | | | | | | | |
| Diptera | | | | | | | | | | |
| Tipulidae | | | | | | | | | | |
| *Antocha saxicola* | | | | | | | | | | |
| *Tipula* sp. | | | | | | | | 1 | | |
| Simuliidae | | | | | | | | | | |
| *Cnephia* sp. | | | | | | | | | | |
| *Prosimulium* sp. | | | | | | 3 | | | | |
| *Simulium* sp. | | | | | | | | 2 | | |
| Chironomidae | | | | | | | | | | |
| *Ablabesmyia* sp. | | | | | | 1 | | | | |
| *Cardiocladius* sp. | | | | | | | | | | |
| *Cladotanytarsus* sp. | | | | | | 17 | 7 | 13 | | 10 |
| *Cricotopus* sp. | | | | | | 5 | | 3 | 3 | 4 |
| *Cryptochironomus* sp. | | | | | | | | | | |
| *Dicrotendipes* sp. | | | | | | | | | | |
| *Endochironomus* sp. | | | | | | | | | | |

APPENDIX XIV Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| Eukiefferiella sp. | | | | | | 3 | 9 | 3 | | 3 |
| Microtendipes sp. | | | | | | | | | | |
| Paratanytarsus sp. | | | | | | | | | | |
| Paratendipes sp. | | | | | | | | | | |
| Pentaneura sp. | | | | | | 1 | | | | |
| Phaenopsectra sp. | | | | | | | | | | |
| Polypedilum sp. | | | | | | 3 | 6 | | | 1 |
| Psectrocladius sp. | | | | | | | | | | |
| Rheotanytarsus sp. | | | | | | | | | | 3 |
| Stictochironomus sp. | | | | | | | | | | |
| Tribelos sp. | | | | | | | | | | |
| Trichocladius sp. | | | | | | | | | | 3 |
| Pupae | | | | | | | | 1 | | |
| Ceratopogonidae | | | | | | | | | | |
| Palpomyia sp. | | | | | | 1 | | | | |
| Tabanidae | | | | | | | | | | |
| Chrysops sp. | | | | | | | | | | |
| Tabanus sp. | | | | | | | | | | |
| Empididae | | | | | | | | | | |
| Hemerodromia sp. | | | | | | | | | | |
| GASTROPODA | | | | | | | | | | |
| Pulmonata | | | | | | | | | | |
| Physidae | | | | | | | | | | |
| Physa sp. | | | | | | 1 | | | | |
| Planorbidae | | | | | | | | | | |
| Gyraulus sp. | | | | | | | | | | |
| Ctenobranchiata | | | | | | | | | | |
| Viviparidae | | | | | | | | | | |
| Lioplax subcarinata | | | | | | 15 | | 10 | 2 | 7 |

APPENDIX XIV Cont.

| | Station R-5 | | | | | Station R-6 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Replicates | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| | | | NO SAMPLE | | | | | | | |
| PELECYPODA | | | | | | | | | | |
| Sphaeridae | | | | | | | | | | |
| _Pisidium_ sp. | | | | | | | | | | |
| _Sphaerium_ sp. | | | | | | 4 | | 6 | | 3 |
| TOTAL NUMBER OF TAXA | | | | | | 32 | 23 | 32 | 19 | 26 |
| TOTAL NUMBER OF ORGANISMS | | | | | | 183 | 175 | 323 | 169 | 223 |

APPENDIX XV

Phylogenetic List of all Benthic Macroinvertebrates Collected from Three Artificial Substrates - Rock Baskets. Radford Army Ammunition Plant. New River, Virginia, October - November 1975.

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Nematophora | | | | | | |
| Gordioidea | | | | | | |
| *Gordius* sp. | | | | | | |
| TURBELLARIA | 7 | 7 | 47 | 11 | 14 | 40 |
| OLIGOCHEATA | | | | | | |
| Plesiopora | | | | | | |
| Tubificidae | | | | | | |
| *Branchiura sowerbyi* | | | 1 | | | |
| *Limnodrilus* sp. | 5 | | 4 | 3 | | |
| Prosopora | | | | | | |
| Lumbriculidae | | | | | | |
| *Lumbriculus* sp. | | | | | | |
| CRUSTACEA | | | | | | |
| Isopoda | | | | | | |
| Asellidae | | | | | | |
| *Asellus* sp. | 1 | | | | | |

APPENDIX XV Cont.

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Amphipoda | | | | | | |
| Talitridae | | | | | | |
| Hyalella azteca | 515 | 245 | 115 | 159 | 139 | 51 |
| Gammaridae | | | | | | |
| Gammarus sp. | 4 | | 7 | 1 | 1 | |
| Decapoda | | | | | | |
| Astacidae | 3 | 4 | 1 | 1 | | |
| Cambarus sp. | | | | | | |
| Orconectes sp. | 3 | 2 | 3 | 0 | | 1 |
| INSECTA | | | | | | |
| Ephemeroptera | | | | | | |
| Ephemeridae | | | | | | |
| Ephemera simulans | 1 | | | | | |
| Caenidae | | | | | | |
| Caenis sp. | | | 1 | | | 1 |
| Ephemerellidae | | | | | | |
| Ephemerella sp. | | | | | | |
| E. deficiens | 320 | 85 | 18 | 381 | 75 | 107 |
| Baetidae | | | | | | |
| Baetis sp. | 1 | | | | | |
| Pseudocloeon sp. | | 2 | 1 | | 2 | |
| Siphlonuridae | | | | | | |
| Isonychia sp. (1) | 64 | 7 | 6 | 82 | 17 | 64 |
| I. sp. (2) | 66 | 21 | 11 | 47 | 30 | 77 |
| Heptageniidae | | | | | | |
| Stenonema sp. (femoratum) | | | | 3 | 1 | |
| Stenonema sp. (interpunctatum) | 138 | 227 | 195 | 74 | 111 | 117 |
| Stenonema sp. (pulchellum) | 404 | 184 | 144 | 532 | 192 | 252 |
| Tricorythodidae | | | | | | |
| Tricorythodes sp. | | | 1 | 1 | | 1 |

APPENDIX XV Cont.

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Odonata | | | | | | |
| Aeschnidae | | | | | | |
| *Boyeria vinosa* | | | | | 1 | 1 |
| Gomphidae | | | | | | |
| *Gomphus fraternus* | | | | | | |
| *G. consanquis* | | | | | | |
| *Ophiogomphus* sp. | | | | | | |
| Coenagrionidae | | | | | | |
| *Argia* sp. | 9 | 3 | 1 | | 2 | 1 |
| *Enallagma* sp. | 1 | | | 1 | | |
| Plecoptera | | | | | | |
| Perlidae | | | | | | |
| *Acroneuria* sp. | | | | | | |
| *Phasganophora capitata* | 4 | 3 | 1 | 1 | | |
| Taeniopterygidae | | | | | | |
| *Taeniopteryx* sp. | | 1 | | | 3 | |
| Megaloptera | | | | | | |
| Sialidae | | | | | | |
| *Sialis* sp. | | | | | | |
| Corydalidae | | | | | | |
| *Corydalus cornutus* | 1 | | | | | |
| *Chauliodes* sp. | | | | | | |
| Trichoptera | | | | | | |
| Hydroptilidae | | | | | | |
| *Agraylea* sp. | | | | | | |
| *Neotrichia* sp. | | | | | 3 | 2 |
| Hydropsychidae | | | | | | |
| *Cheumatopsyche* sp. | 123 | 50 | 6 | 116 | 44 | 112 |
| *Hydropsyche* sp. | 405 | 173 | 21 | 338 | 190 | 125 |
| *Macronemum* sp. | | | | | | 1 |

APPENDIX XV Cont.

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Psychomyiidae | | | | | | |
| *Polycentropus remotus* | 2 | 4 | 3 | | 2 | 4 |
| Leptoceridae | | | | | | |
| *Oecetis cinerascens* | | | | | | |
| *Triaenodes injusta* | 2 | | 2 | 3 | | |
| Lepidostomatidae | | | | | | |
| *Lepidostoma* sp. | 2 | | 1 | | | 1 |
| Brachycentridae | | | | | | |
| *Brachycentrus* sp. | | 2 | | 1 | 1 | |
| *Micrasema* sp. | | | | 1 | | |
| Molannidae | | | | | | |
| *Molanna* | | | | | | |
| Coleoptera | | | | | | |
| Elmidae | | | | | | |
| *Dubiraphia* sp. | 1 | | 1 | 1 | | 1 |
| *Macronychus* sp. | | | | | | 5 |
| *Optioservus* sp. | 5 | 1 | 1 | 3 | | |
| *Stenelmis* sp. | 1 | | | | | |
| Haliplidae | | | | | | |
| *Peltodytes* sp. | | | | 1 | | |
| Limnichidae | | | | | | |
| *Lutrochus* sp. | | | | | | |
| Diptera | | | | | | |
| Tipulidae | | | | | | |
| *Tipula* sp. | | | | | | |
| Simuliidae | | | | | | |
| *Simulium* sp. | 15 | 3 | 1 | 19 | 21 | 13 |
| Chironomidae | | | | | | |
| *Ablabesmyia* sp. | | | | | | |
| *Chironomus* sp. | 2 | | | | | |

APPENDIX XV Cont.

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Cladotanytarsus sp. | 52 | 119 | | 179 | 49 | 7 |
| Cricotopus sp. | 1 | | | | | |
| Eukiefferiella sp. 1 | 26 | 15 | 3 | 31 | 23 | 11 |
| E. sp. 2 | | 1 | | 54 | 74 | |
| Pentaneura sp. | 3 | 1 | | 9 | 4 | 2 |
| Phaenopsectra sp. | 1 | | | | | |
| Polypedilum sp. | 4 | 5 | 3 | 13 | 1 | 1 |
| Psectrocladius sp. | | 11 | | 1 | | |
| Rheotanytarsus sp. | | | 6 | | | |
| Stenochironomus sp. | | | | | | 1 |
| Stictochironomus sp. | | | | | | |
| Tanytarsus sp. | | | 1 | | | |
| Thienemanniella sp. | | 2 | | 7 | 1 | |
| Tribelos sp. | | | 1 | | | 1 |
| Pupae | | | 2 | | 1 | |
| Ceratopogonidae | | | | | | |
| Palpomyia sp. | | | | | | |
| Empididae | | | | | | |
| Hemerodromia | | | | | | |
| GASTROPODA | | | | | | |
| Pulmonata | | | | | | |
| Physidae | | | | | | |
| Physa sp. | 3 | 4 | | 1 | | 1 |
| Planorbidae | | | | | | |
| Gyraulus sp. | | | | | | |
| Ctenobranchiata | | | | | | |
| Viviparidae | | | | | | |
| Lioplax subcarinata | 8 | 10 | 2 | 3 | 8 | 8 |
| Ancylidae | | | | | | |
| Ferrissia | | | 1 | 1 | | |

APPENDIX XV Cont.

| | Station R-1 | | | Station R-2 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| PELECYPODA | | | | | | |
| Sphaeridae | | | | | | |
| *Pisidium* sp. | | | | | | |
| *Sphaerium* sp. | 9 | 2 | 1 | | | 13 |
| Total Number of Taxa | 37 | 29 | 34 | 33 | 27 | 30 |
| Total Number of Organisms | 2212 | 1094 | 613 | 2079 | 1010 | 1022 |

APPENDIX XV

Phylogenetic List of all Benthic Macroinvertebrates Collected from
Three Artificial Substrates - Rock Baskets. Radford Army Ammunition Plant.
New River, Virginia, October - November 1975.

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Nematophora | | | | | | |
| Gordioidea | | | | | | |
| *Gordius* sp. | | | | | | |
| TURBELLARIA | 8 | 12 | 12 | | 37 | 20 |
| OLIGOCHEATA | | | | | | |
| Plesiopora | | | | | | |
| Tubificidae | | | | | | |
| *Branchiura sowerbyi* | | 1 | | | | |
| *Limnodrilus* sp. | 3 | 1 | 3 | | | 3 |
| Prosopora | | | | | | |
| Lumbriculidae | | | | | | |
| *Lumbriculus* sp. | | | | | | |
| CRUSTACEA | | | | | | |
| Isopoda | | | | | | |
| Asellidae | | | | | | |
| *Asellus* sp. | | | | | | 1 |

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Amphipoda | | | | | | |
| Talitridae | | | | | | |
| Hyalella azteca | 21 | 69 | 60 | 34 | 131 | 216 |
| Gammaridae | | | | | | |
| Gammarus sp. | 5 | 4 | 4 | 3 | 21 | 9 |
| Decapoda | | | | | | |
| Astacidae | 2 | 1 | 5 | 2 | 2 | |
| Cambarus sp. | | | | | 1 | 1 |
| Orconectes sp. | | 2 | | 2 | 1 | 1 |
| INSECTA | | | | | | |
| Ephemeroptera | | | | | | |
| Ephemeridae | | | | | | |
| Ephemera simulans | | | | | | |
| Caenidae | | | | | | |
| Caenis sp. | | | 1 | | 1 | 2 |
| Ephemerellidae | | | | | | |
| Ephemerella sp. | 14 | 74 | 153 | 41 | 36 | 237 |
| E. deficiens | | | | | | |
| Baetidae | | | | | | |
| Baetis sp. | | | | 2 | | |
| Pseudocloeon sp. | | 1 | | 2 | | |
| Siphlonuridae | | | | | | |
| Isonychia sp. (1) | 20 | 31 | 53 | 9 | 12 | 29 |
| I. sp. (2) | 37 | 51 | 68 | 4 | 16 | 21 |
| Heptageniidae | | | | | | |
| Stenonema sp. (femoratum) | 1 | | | | | |
| Stenonema sp. (interpunctatum) | 172 | 39 | 61 | 99 | 178 | 106 |
| Stenonema sp. (pulchellum) | 206 | 442 | 375 | 200 | 236 | 475 |
| Tricorythodidae | | | | | | |
| Tricorythodes sp. | | 2 | 1 | 1 | 5 | 9 |

APPENDIX XV Cont.

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Odonata | | | | | | |
| Aeschnidae | | | | | | |
| *Boyeria vinosa* | | | | | | |
| Gomphidae | | | | | | |
| *Gomphus fraternus* | | | | | | |
| *G. consanquis* | | | | | | |
| *Ophiogomphus* sp. | | | | | | |
| Coenagrionidae | | | | | | |
| *Argia* sp. | 1 | | 1 | | 4 | 2 |
| *Enallagma* sp. | | | | | | 1 |
| Plecoptera | | | | | | |
| Perlidae | | | | | | |
| *Acroneuria* sp. | | | 1 | | | |
| *Phasganophora capitata* | | | | | | |
| Taeniopterygidae | | | | | | |
| *Taeniopteryx* sp. | | | | 1 | 1 | 2 |
| Megaloptera | | | | | | |
| Sialidae | | | | | | |
| *Sialis* sp. | | | | | | |
| Corydalidae | | | | | | |
| *Corydalus cornutus* | | | | | | |
| *Chauliodes* sp. | | | | | | |
| Trichoptera | | | | | | |
| Hydroptilidae | | | | | | |
| *Agraylea* sp. | | | | | | |
| *Neotrichia* sp. | 1 | | | | | |
| Hydropsychidae | | | | | | |
| *Cheumatopsyche* sp. | 20 | 86 | 51 | 10 | 15 | 96 |
| *Hydropsyche* sp. | 38 | 118 | 120 | 42 | 40 | 135 |
| *Macronemum* sp. | | | | | | 1 |

APPENDIX XV Cont.

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Psychomyiidae | | | | | | |
| Polycentropus remotus | 2 | 1 | 1 | 4 | 6 | 19 |
| Leptoceridae | | | | | | |
| Oecetis cinerascens | | 1 | 1 | | | 1 |
| Triaenodes injusta | | 1 | | 1 | | 3 |
| Lepidostomatidae | | | | | | |
| Lepidostoma sp. | | | 1 | | 3 | 1 |
| Brachycentridae | | | | | | |
| Brachycentrus sp. | | | | | 3 | |
| Micrasema sp. | | | | 1 | | |
| Molannidae | | | | | | |
| Molanna | | | | | | |
| Coleoptera | | | | | | |
| Elmidae | | | | | | |
| Dubiraphia sp. | | | | | | |
| Macronychus sp. | | | | | | |
| Optioservus sp. | | 1 | 2 | | | 2 |
| Stenelmis sp. | | | | | | |
| Haliplidae | | | | | | |
| Peltodytes sp. | | | | | | |
| Limnichidae | | | | | | |
| Lutrochus sp. | | | | | | |
| Diptera | | | | | | |
| Tipulidae | | | | | | |
| Tipula sp. | | | | | | 1 |
| Simuliidae | | | | | | |
| Simulium sp. | 9 | 1 | 8 | 8 | 6 | 2 |
| Chironomidae | | | | | | |
| Ablabesmyia sp. | | | 1 | | 1 | 1 |
| Chironomus sp. | 1 | | | | | |

APPENDIX XV Cont.

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Cladotanytarsus sp. | 5 | 20 | 71 | 39 | 43 | 83 |
| Cricotopus sp. | | | | | | |
| Eukiefferiella sp. 1 | | 8 | 33 | | 1 | 4 |
| E. sp. 2 | | 3 | | | 3 | |
| Pentaneura sp. | | | 2 | 5 | 1 | 9 |
| Phaenopsectra sp. | | | | | | |
| Polypedilum sp. | | | | | 1 | 2 |
| Psectrocladius sp. | | | 1 | 2 | 7 | 3 |
| Rheotanytarsus sp. | | | | | | 13 |
| Stenochironomus sp. | | | | | | 1 |
| Stictochironomus sp. | | | | | | |
| Tanytarsus sp. | | | | | | |
| Thienemanniella sp. | | 4 | 3 | 1 | 5 | 6 |
| Tribelos sp. | | | | | | |
| Pupae | | 1 | | | 1 | 1 |
| Ceratopogonidae | | | | | | |
| Palpomyia sp. | | | | | | |
| Empididae | | | | | | |
| Hemerodromia | | | | | | |
| GASTROPODA | | | | | | |
| Pulmonata | | | | | | |
| Physidae | | | | | | |
| Physa sp. | | | | | | |
| Planorbidae | | | | | | |
| Gyraulus sp. | | | | | | |
| Ctenobranchiata | | | | | | |
| Viviparidae | | | | | | |
| Lioplax subcarinata | 9 | 8 | 3 | 9 | 8 | 5 |
| Ancylidae | | | | | | |
| Ferrissia | | | | | 4 | |

APPENDIX XV Cont.

| | Station R-3 | | | Station R-4 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| PELECYPODA | | | | | | |
| Sphaeridae | | | | | | |
| *Pisidium* sp. | 9 | | | 4 | | |
| *Sphaerium* sp. | | | 1 | | 9 | 1 |
| Total Number of Taxa | 21 | 27 | 29 | 25 | 33 | 39 |
| Total Number of Organisms | 579 | 983 | 1097 | 530 | 839 | 1525 |

## APPENDIX XV

Phylogenetic List of all Benthic Macroinvertebrates Collected from
Three Artificial Substrates - Rock Baskets. Radford A.my Ammunition Plant.
New River, Virginia, October - November 1975.

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Nematophora | | NS* | | | | |
| Gordioidea | | | | | | |
| Gordius sp. | | | | | | |
| TURBELLARIA | | | | 94 | 22 | 97 |
| OLIGOCHEATA | | | | | | |
| Plesiopora | | | | | | |
| Tubificidae | | | | | | |
| Branchiura sowerbyi | | | | | 1 | |
| Limnodrilus sp. | | | | | 10 | 7 |
| Prosopora | | | | | | |
| Lumbriculidae | | | | | | |
| Lumbriculus sp. | | | | 8 | | |
| CRUSTACEA | | | | | | |
| Isopoda | | | | | | |
| Asellidae | | | | | | |
| Asellus sp. | | | | 1 | | 5 |

APPENDIX XV Cont.

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Amphipoda | | | | | | |
| Talitridae | | | | | | |
| *Hyalella azteca* | | | | 169 | 53 | 212 |
| Gammaridae | | | | | | |
| *Gammarus* sp. | | | | 251 | 8 | 39 |
| Decapoda | | | | | | |
| Astacidae | | | | 5 | | 4 |
| *Cambarus* sp. | | | | | | |
| *Orconectes* sp. | | | | 3 | | 6 |
| INSECTA | | | | | | |
| Ephemeroptera | | | | | | |
| Ephemeridae | | | | | | |
| *Ephemera simulans* | | | | | | |
| Caenidae | | | | | | |
| *Caenis* sp. | | | | 2 | | 2 |
| Ephemerellidae | | | | | | |
| *Ephemerella* sp. | | | | | | |
| *E. deficiens* | | | | 202 | 10 | 175 |
| Baetidae | | | | | | |
| *Baetis* sp. | | | | | | |
| *Pseudocloeon* sp. | | | | 1 | | 4 |
| Siphlonuridae | | | | | | |
| *Isonychia* sp. (1) | | | | 54 | | 111 |
| *I.* sp. (2) | | | | 181 | 2 | 263 |
| Heptageniidae | | | | | | |
| *Stenonema* sp. (femoratum) | | | | | | |
| *Stenonema* sp. (interpunctatum) | | | | 105 | 3 | 123 |
| *Stenonema* sp. (pulchellum) | | | 581 | 31 | 782 | |
| Tricorythodidae | | | | | | |
| *Tricorythodes* sp. | | | | 3 | | 9 |

APPENDIX XV Cont.

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Odonata | | | | | | |
| Aeschnidae | | | | | | |
| *Boyeria vinosa* | | | | | | |
| Gomphidae | | | | | | |
| *Gomphus fraternus* | | | | | 1 | |
| *G. consanquis* | | | | | | |
| *Ophiogomphus* sp. | | | | | | |
| Coenagrionidae | | | | | | |
| *Argia* sp. | | | | 3 | | 3 |
| *Enallagma* sp. | | | | | | |
| Plecoptera | | | | | | |
| Perlidae | | | | | | |
| *Acroneuria* sp. | | | | | | 2 |
| *Phasganophora capitata* | | | | | | 3 |
| Taeniopterygidae | | | | | | |
| *Taeniopteryx* sp. | | | | | | 1 |
| Megaloptera | | | | | | |
| Sialidae | | | | | | |
| *Sialis* sp. | | | | | 1 | |
| Corydalidae | | | | | | |
| *Corydalus cornutus* | | | | | | 1 |
| *Chauliodes* sp. | | | | 1 | | |
| Trichoptera | | | | | | |
| Hydroptilidae | | | | | | |
| *Agraylea* sp. | | | | | | |
| *Neotrichia* sp. | | | | | | |
| Hydropsychidae | | | | | | |
| *Cheumatopsyche* sp. | | | | 45 | 2 | 55 |
| *Hydropsyche* sp. | | | | 140 | 33 | 120 |
| *Macronemum* sp. | | | | | | |

APPENDIX XV Cont.

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Psychomyiidae | | | | | | |
| *Polycentropus remotus* | | | | 10 | 2 | 15 |
| Leptoceridae | | | | | | |
| *Oecetis cinerascens* | | | | | | 1 |
| *Triaenodes injusta* | | | | | 1 | 1 |
| Lepidostomatidae | | | | | | |
| *Lepidostoma* sp. | | | | 3 | 1 | 3 |
| Brachycentridae | | | | | | |
| *Brachycentrus* sp. | | | | | | |
| *Micrasema* sp. | | | | | | |
| Molannidae | | | | | | |
| *Molanna* | | | | | | 1 |
| Coleoptera | | | | | | |
| Elmidae | | | | | | |
| *Dubiraphia* sp. | | | | | | |
| *Macronychus* sp. | | | | | | |
| *Optioservus* sp. | | | | 9 | 4 | 2 |
| *Stenelmis* sp. | | | | | | |
| Haliplidae | | | | | | |
| *Peltodytes* sp. | | | | | | |
| Limnichidae | | | | | | |
| *Lutrochus* sp. | | | | 1 | | |
| Diptera | | | | | | |
| Tipulidae | | | | | | |
| *Tipula* sp. | | | | | | |
| Simuliidae | | | | | | |
| *Simulium* sp. | | | | 5 | | 8 |
| Chironomidae | | | | | | |
| *Ablabesmyia* sp. | | | | | | 1 |
| *Chironomus* sp. | | | | | | |

APPENDIX XV Cont.

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| *Cladotanytarsus* sp. | | | | 3 | 3 | 40 |
| *Cricotopus* sp. | | | | 3 | | |
| *Eukiefferiella* sp. 1 | | | | 1 | 1 | 17 |
| *E.* sp. 2 | | | | | 1 | 1 |
| *Pentaneura* sp. | | | | 6 | 1 | 6 |
| *Phaenopsectra* sp. | | | | | | |
| *Polypedilum* sp. | | | | | 1 | 2 |
| *Psectrocladius* sp. | | | | | | 8 |
| *Rheotanytarsus* sp. | | | | | | |
| *Stenochironomus* sp. | | | | | | |
| *Stictochironomus* sp. | | | | | 1 | |
| *Tanytarsus* sp. | | | | | | |
| *Thienemanniella* sp. | | | | | 3 | 9 |
| *Tribelos* sp. | | | | | | |
| Pupae | | | | | | 1 |
| Ceratopogonidae | | | | | | |
| *Palpomyia* sp. | | | | 1 | | |
| Empididae | | | | | | |
| *Hemerodromia* | | | | | | |
| GASTROPODA | | | | | | |
| Pulmonata | | | | | | |
| Physidae | | | | | | |
| *Physa* sp. | | | | | 4 | |
| Planorbidae | | | | | | |
| *Gyraulus* sp. | | | | 1 | | |
| Ctenobranchiata | | | | | | |
| Viviparidae | | | | | | |
| *Lioplax subcarinata* | | | | 42 | 5 | 6 |
| Ancylidae | | | | | | |
| *Ferrissia* | | | | | | |

APPENDIX XV Cont.

| | Station R-5 | | | Station R-6 | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| PELECYPODA | | | | | | |
| Sphaeridae | | | | | | |
| *Pisidium* sp. | | | | 23 | | |
| *Sphaerium* sp. | | | | | 84 | 5 |
| Total Number of Taxa | | | | 32 | 28 | 41 |
| Total Number of Organisms | | | | 1731 | 290 | 2132 |

*NS = No sample

## APPENDIX XVI

Phylogenetic List of Benthic Macroinvertebrates Collected from
Natural Substrates - Single Sample Using the Kick Method. Radford Army Ammunition Plant.
New River, Virginia. November, 1975.

| | Stations | | | | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | R6 |
| NEMATOMORPHA | | | | | NS* | |
| Gordioidea | | | | | | |
| Gordiidae | | | | | | |
| *Gordius* sp. | | | | | | 3 |
| TURBELLARIA | 9 | 3 | 3 | 7 | | 5 |
| Tricladia | | | | | | |
| Planariidae | | | | | | |
| *Dugesia* sp. | | | | | | |
| OLIGOCHEATA | | | | | | |
| Plesiopora | | | | | | |
| Tubificidae | | | | | | |
| *Aulodrilus* sp. | | 8 | 6 | | | 2 |
| *Branchiura sowerbyi* | 10 | 5 | 13 | | | |
| *Limnodriulus* sp. | 303 | 20 | 44 | | | 11 |
| HIRUDINEA | | | | | | |
| Glossiphoniidae | | | | | | |
| *Placobdella* | | 1 | | | | |

APPENDIX XVI Cont.

| | Stations R1 | R2 | R3 | R4 | R5 | R6 |
|---|---|---|---|---|---|---|
| CRUSTACEA | | | | | | |
| Isopoda | | | | | | |
| Asellidae | | | | | | |
| Asellus sp. | | | | | | 3 |
| Amphipoda | | | | | | |
| Talitridae | | | | | | |
| Hyalella azteca | 796 | 50 | 82 | 5 | | 34 |
| Gammaridae | | | | | | |
| Gammarus sp. | 24 | 3 | 5 | 2 | | 4 |
| Decapoda | | | | | | |
| Astacidae | 1 | 1 | | 3 | | |
| Orconectes sp. | 2 | 2 | | | | |
| INSECTA | | | | | | |
| Ephemeroptera | | | | | | |
| Ephemeridae | | | | | | |
| Ephemera simulans | 3 | 2 | 2 | | | 1 |
| Caenidae | | | | | | |
| Ephemerellidae | | | | | | |
| Ephemerella sp. | | | | | | |
| E. deficiens | 134 | 13 | 10 | 23 | | 22 |
| Baetidae | | | | | | |
| Baetis sp. | | | | | | |
| Centroptilum sp. | 1 | | | | | |
| Pseudocloeon sp. | 5 | 1 | 1 | 2 | | |
| Siphlonuridae | | | | | | |
| Isonychia sp. (1) | | | | | | |
| I. sp. (2) | 1 | | 4 | 21 | | 2 |
| Heptageniidae | | | | | | |
| Stenonema sp. (interpunctatum) | 3 | 5 | 21 | 20 | | |
| Stenonema sp. (pulchellum) | 327 | 79 | 110 | 227 | | 79 |

APPENDIX XVI Cont.

| | Stations | | | | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | R6 |
| Tricorythodidae | | | | | | |
| *Tricorythodes* sp. | 6 | 2 | 2 | | | 3 |
| Odonata | | | | | | |
| Calopterygidae | | | | | | |
| *Hetaerina* sp. | | | 1 | | | |
| Gomphidae | | | | | | |
| *Gomphus fraternus* | 2 | 1 | | | | |
| *Ophiogomphus* sp. | | | 1 | | | |
| Coenagrionidae | | | | | | |
| *Argia* sp. | 15 | 1 | 2 | 11 | | |
| *Enallagma* sp. | 8 | 2 | 6 | | | |
| Plecoptera | | | | | | |
| Perlidae | | | | | | |
| *Phasganophora capitata* | 6 | | | | | |
| Taeniopterygidae | | | | | | |
| *Taeniopteryx* sp. | | 1 | 1 | | | |
| Megaloptera | | | | | | |
| Sialidae | | | | | | |
| *Sialis* sp. | | 1 | | | | 1 |
| Trichoptera | | | | | | |
| Hydropsychidae | | | | | | |
| *Cheumatopsyche* sp. | 24 | 5 | 5 | 23 | | 6 |
| *Hydropsyche* sp. | 452 | 109 | 74 | 86 | | 129 |
| *Macronemum* sp. | | | | 1 | | |
| Psychomyiidae | | | | | | |
| *Polycentropus remotus* | 13 | 2 | 2 | 2 | | 3 |
| Leptoceridae | | | | | | |
| *Athripsodes* sp. *a* | 1 | | | | | |
| *Mystacides sepulchuralis* | 1 | | | | | 2 |

APPENDIX XVI Cont.

| | Stations R1 | R2 | R3 | R4 | R5 | R6 |
|---|---|---|---|---|---|---|
| *Oecetis cinerascens* | 6 | | | | | |
| *Triaenodes* sp. | | | | | | |
| *T. injusta* | 21 | 8 | 6 | | | 8 |
| *T. tarda* | 11 | | 1 | | | |
| Lepidostomatidae | | | | | | |
| *Lepidostoma* sp. | 15 | 1 | 5 | 1 | | 5 |
| Brachycentridae | | | | | | |
| *Brachycentrus* sp. | 2 | | | | | |
| *Micrasema* sp. | | | | | | |
| Coleoptera | | | | | | |
| Dytiscidae | | | | | | |
| *Colymbetes* sp. | 1 | | | | | |
| Elmidae | | | | | | |
| *Dubiraphia* sp. | 50 | 6 | 4 | | | 19 |
| *Optioservus* sp. | 132 | 12 | 18 | 7 | 10 | |
| *Stenelmis* sp. | | 2 | | | | 2 |
| Psephenidae | | | | | | |
| *Psephenus* sp. | | | | 1 | | |
| Diptera | | | | | | |
| Tipulidae | | | 1 | | | |
| Simuliidae | | | | | | |
| *Simulium* sp. | 3 | 1 | | 2 | | 2 |
| Chironomidae | | | | | | |
| *Ablabesmyia* sp. | 3 | | | | | |
| *Cladotanytarsus* sp. | 98 | 9 | 2 | 7 | | 14 |
| *Corynoneura* sp. | | | | 1 | | |
| *Cryptochironomus* ps. | | | | | | 1 |
| *Eukiefferiella* sp. | 44 | 3 | 1 | | | 1 |
| *Pentaneura* sp. | 2 | | 2 | | | 1 |

| | Stations | | | | | |
|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | R6 |
| *Polypedilum* sp. | | 1 | | 1 | | 4 |
| *Psectrocladius* sp. | 23 | | | | | |
| *Rheotanytarsus* sp. | 1 | | | | | |
| *Stenochironomus* sp. | | | | | | 1 |
| *Thienemanniella* sp. | 1 | | | | | |
| *Tribelos* sp. | 11 | 2 | 4 | | | 2 |
| Pupae | 2 | 2 | | | | |
| Empidae | | | | | | |
| *Hemerodromia* | | 1 | | | | 1 |
| GASTROPODA | | | | | | |
| Pulmonata | | | | | | |
| Physidae | | | | | | |
| *Physa* sp. | 46 | 2 | 13 | | | 3 |
| Planorbidae | | | | | | |
| *Gyraulus* sp. | 3 | | 1 | | | |
| Lymnaeidae | | | | | | |
| *Fossaria* sp. | 1 | | | | | |
| Ctenobrachiata | | | | | | |
| Viviparidae | | | | | | |
| *Lioplax subcarinata* | 1 | | 4 | | | 1 |
| Ancylidae | | | | | | |
| *Ferrissa* sp. | | | 1 | | | |
| PELECYPODA | | | | | | |
| Sphaeridae | | | | | | |
| *Pisidium* sp. | | | | | | |
| *Sphaerium* sp. | 52 | 12 | 16 | 9 | | 47 |
| Total Number of Taxa | 47 | 37 | 36 | 22 | | 34 |
| Total Number of Organisms | 2676 | 379 | 474 | 462 | | 432 |

°NS = No sample

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